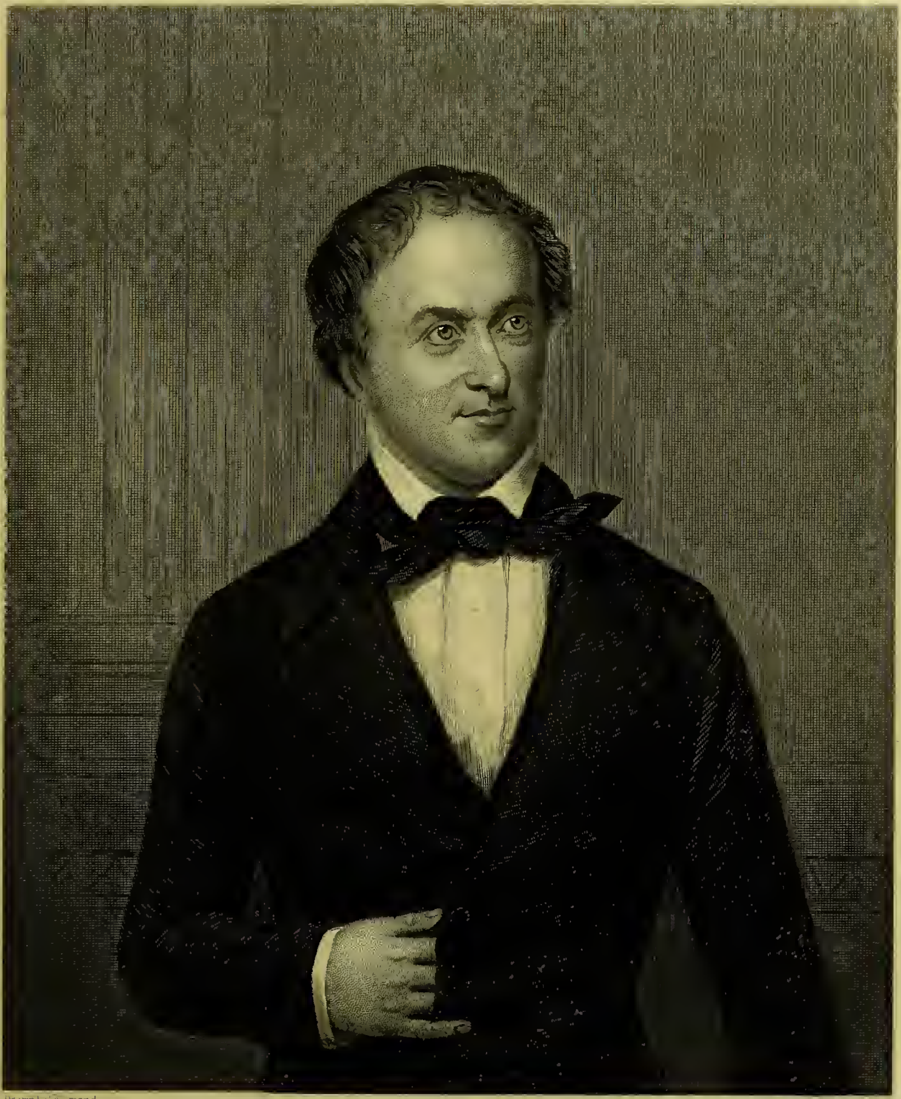
CHEMISTRY
AS
APPLIED
TO
ARTS & MANUFACTURES.
BY
Dr S.
MUSPRATT

22102072760

Med
K1385

23662

79727



Drawn by Lallemand

Engraved by W. [illegible] Sharpe

PROFESSOR ROSE, F.R.S.

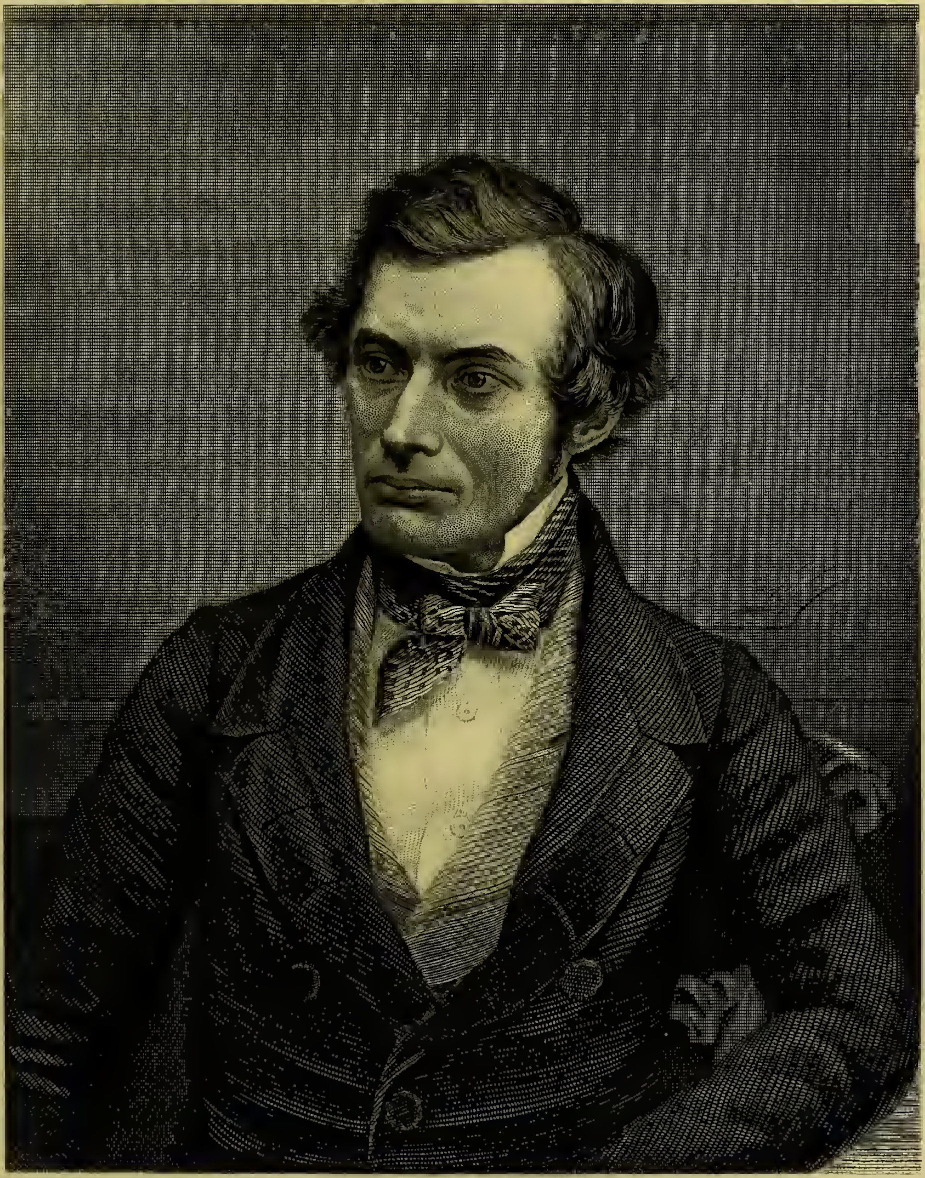
OF THE ROYAL UNIVERSITY OF BERLIN &c

Heinrich Rose.

[illegible] MACKENZIE [illegible] OW, EDINBURGH, LONDON & NE

WELLCOME INSTITUTE
LIBRARY

Coll.	welMOmec
Call	
No.	QD
	1966



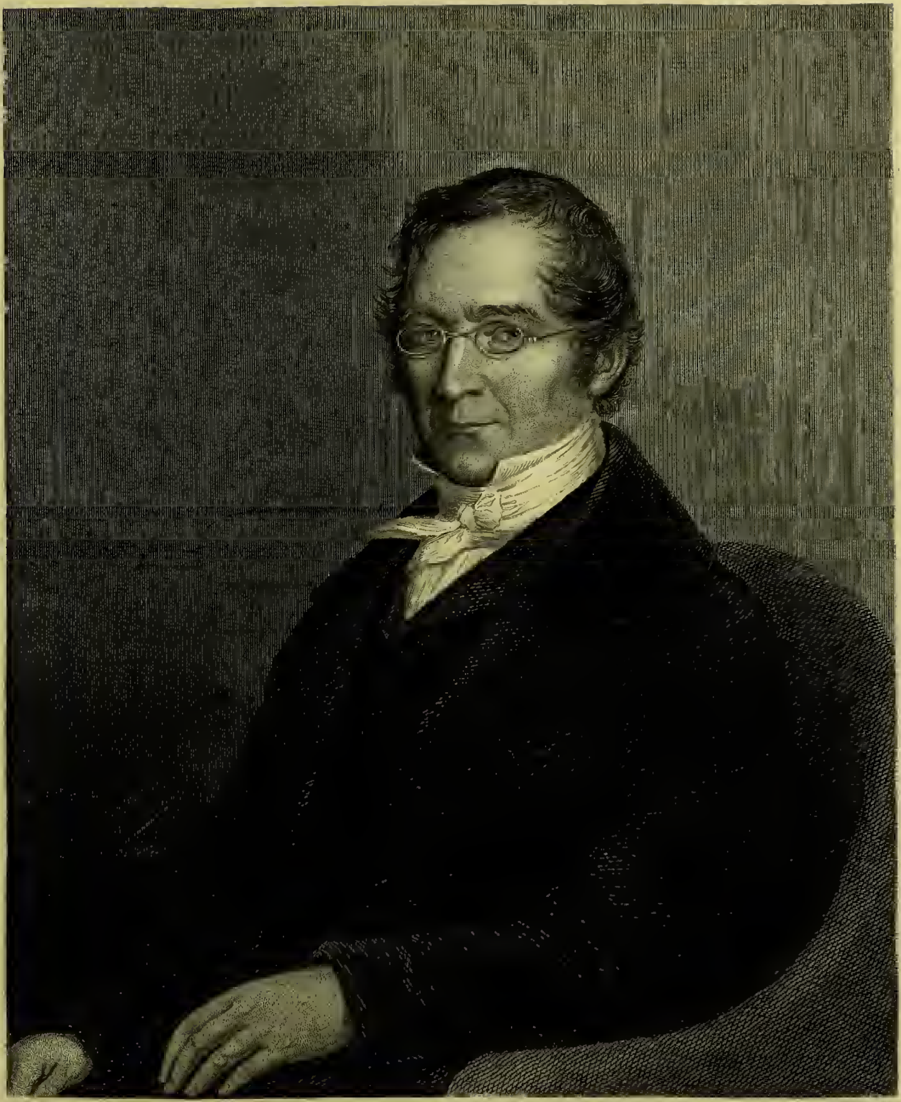
Engraved by C. Cook, from a Photograph by Claudet.

PROFESSOR GRAHAM, F.R.S.

MASTER OF HER MAJESTY'S MINT.

Tho. Graham

[illegible] EDINBURGH, LONDON & NEW-YORK



Belliard C W [illegible]

PROFESSOR GAY-LUSSAC, F.R.S.

MEMBRE DE L' INSTITUT, PROFESSOR AT THE UNIVERSITY OF PARIS &c

Gay Lussac

Thomas Lawrence [illegible]

SIR HUMPHRY DAVY,

PROFESSOR OF CHEMISTRY, ROYAL INSTITUTION, LONDON

H. Davy

WILLIAM MACKENZIE, GLASGOW, EDINBURGH, LONDON & NEW YORK

Drawn by Weinand

Engraved by [illegible]

PROFESSOR MITSCHERLICH F.R.S. &c.

ROYAL UNIVERSITY OF BERLIN

E. Mitscherlich.

WILLIAM MACKENZIE, GLASGOW, EDINBURGH, LONDON & NEW YORK

INDEX TO ARTICLES.

ACETIC ACID—1-48.
acetate of alumina, 36.
″ ammonia, 38.
″ copper, 38.
″ iron, 41–43.
″ lead, 43–45.
″ lime, 28, 45, 46.
″ manganese, 46.
″ oxide of ethyle, 41.
″ protoxide of tin, 48.
″ zinc, 48.
acetic ether, 41.
acetone, 32.
acetous fermentation, 4–6.
acid, aldehydic, 14.
″ lampic, 14.
″ pyroligneous, 16–25.
adulterations, 33–35.
aldehyde, 4, 14.
alkalimeter, 32.
alumina, sesquiacetate of, 36–38.
ammonia, acetate of, 38.
applications of, 35, 36.
aromatic vinegar, 31, 32.
AZULAY and SOLOMONS' patent carbonizing process, by steam, 24.
beer vinegar, 16.
beet-root vinegar, 15, 16.
bibasic acetate of copper, 39–41.
BRANDE's method of testing vinegar, 32.
brandy vinegar, acetic acid from, 31.
carbonizer, M. SCHWARTZ's, 18.
carbonizing furnace, REICHENBACH's, 19.
″ process by steam, 24.
copper, acetate of, 38–41.
dyewoods, wood-vinegar from, 23.
ether, acetic, 41.
ethyle, acetate of the oxide of, 41.
excise duty on vinegar, 32.
fermentation, acetous, 4–6.
″ saccharine, 9.
fielding, 11.
formation and properties of, 2.
fruit vinegar, 16.
HALLIDAY's patent process for manufacturing pyroligneous acid, 23.
HAM's patent vinegar process, 15.
iron, acetates of, 41–43.
lead, brown acetate of, 43.
″ white acetate of. 44.
lime, acetate of, 28, 45, 46.
liquor ammoniæ acetatis, 38.
malt vinegar, 8–12.
manganese, acetate of, 46.
Mindererus, spirit of, 38.
mordant, red liquor, 37.
mother of vinegar, 5.
MULDER's account of *Mycoderma aceti*, 7.
naphtha, wood, 25–27.
NEALE and DUYCK's process for manufacturing vinegar from beet-root, 15, 16.
PAUR's process, 24, 25.
production of, from alcohol, 3, 4.
pure acetic acid from brandy vinegar, 31.
pyroligneous acid or wood-vinegar, 16-25.
″ ″ purification of, 27–31.
pyroxilic spirit, or wood-naphtha, 25–27.
″ ″ purification of, 26.
quick vinegar process, 12–15.
RANDALL's account of the wood vinegar manufacture, 24.
red liquor, 37.
REICHENBACH's carbonizing furnace, 19.
saccharine fermentation, 9.
safety-tube, WELTER's, 31.
salt of Saturn, 43.
saw-dust, wood-vinegar from, 23.
SCHWARTZ's carbonizer, 18.
sea-weed, a source of vinegar, 16.
sesquiacetate of alumina, 36–38.
soda, acetate of, 28, 47, 48.
SOLOMONS and AZULAY's patent carbonizing process, by steam, 24.

ACETIC ACID, *continued.*
spirit of Mindererus, 38.
″ pyroxilic, 25–27.
statistics of the vinegar manufacture, 36.
steam, patent carbonizing process, 24.
sugar, vinegar from, 12.
″ of lead, 43–45.
testing vinegar, methods of, 32, 33.
tin, acetate of the protoxide of, 48.
uses and applications, 36.
verdigris, 39–41.
vessels in which vinegar should be kept, 36.
vinegar, aromatic, 31, 32.
″ from beer, 16.
″ from beet-root, 15, 16.
″ concentration of, 35.
″ duty on, 32.
″ fruit, 16.
″ malt, 8–12.
″ manufacture of, 6, 7.
″ sea-weed, 16.
″ manufacture, statistics of, 36.
″ testing, methods of, 32, 33.
″ vessels for keeping, 36.
″ wood, 16–25.
″ mother of, 5.
″ uses of, 35.
″ warehouse, 12.
VÖLCKEL's process for preparing pure acetic acid from brandy vinegar, 31.
WELTER's safety-tube, 31.
wood, composition of, 17, 18.
″ distillation of, 17.
″ naphtha, 25–27.
″ products of, by distillation, 22.
″ vinegar, or pyrolig. acid, 16–25.
″ ″ HALLIDAY's process, 23.
″ ″ purification of, 27–31,
zinc, acetate of, 48.

ALCOHOL—48-149.
absolute, specific gravity of, 52.
action on acids, 55.
″ with metallic salts, 55.
ADAM's still, 78, 79.
adulterations, 145, 146.
alcoholometer, FIELD's, 136, 137.
alcoholometry, 117–145.
″ FOWNES' tables, 139.
″ GAY-LUSSAC's, 123-1
″ LOWITZ's table, 131.
″ SILBERMANN's dilatometer, 140–142.
″ table of comparison, 131.
″ TRALLES' tables, 118–122.
″ URE's table, 135.
ALÈGRE's still, 89–92.
almond cake, 102.
amyle, 49.
analysis of, 54.
angelica root, 102.
aqua vitæ, 57.
arrack, 106, 114, 115.
attenuation of worts, 65, 66.
beer from potatoes, 113.
BERARD's still, 82.
boiling points of, by URE, 136.
brandy, 103–106.
″ artificial formation of, 105.
″ cherry, 106.
″ flavor, receipt for, 106.
″ from marcs, 104.
″ raspberry, 105.
″ in Switzerland, 106.
British spirit, 98.
bubs, 66.
Bushmills distilleries, 94.
calamus root, 102.
Canada, distillery in, 97, 98.
carbonic acid, in fermentation, 65.
cardamom, 102.
carrot spirit, 115, 116.

ALCOHOL, *continued.*
cassia, 103.
ceryle, 49.
charcoal, a deodorizer of spirits, 99.
cherry brandy, 106.
″ tincture, 106.
chloroform, 55.
″ quality of, injured by high duty on alcohol, 56.
Cingalese still, 115.
cognac, 104.
coolers, 64.
cooling the wort, 63, 64.
concentration of, 50–52.
coriander, 103.
definition of, general, 50.
dehydration of, 50–52.
DEROSNE's still, 82–84.
diastase, 62, 70, 71.
DICAS' hydrometer, 142.
dilatometer, SILBERMANN's, 140–142.
distillation, 71–94.
″ acceleration of, 74.
″ fuel consumed, 78.
″ general description of, 72.
″ illicit, MOREWOOD's account of, 95–97.
″ improvements in, checked by excise system, 73.
″ principle of, 71.
distilleries, Bushmills, 94.
″ excise rules, 58, 72, 73.
″ size of, 78.
distillery in Canada, 97, 98.
″ in London, general description of, 57.
distilling and brewing, points of difference, 59.
DORN's still, 87.
DUBRUNFAUT's improvement in rum distillation, 112.
dunder, 107.
duty on, evils of, 55, 56.
elastic force of alcohol vapor, 54.
enanthic ether in brandy, 105.
ethyle, 49.
excise laws, 63.
″ ″ alteration of, 74.
″ ″ supervision of distilleries, 58.
expansion of, by heat, 54.
faints, 72.
fermentation, 64–71.
″ cause of, 69.
″ precautions necessary, 66.
″ principles of, 66, 67.
″ spontaneous, 70.
″ time and temperature, 65.
FIELD's alcoholometer, by URE, 136, 137.
″ ″ tables adapted to, 138.
foreshot, 99.
FOWNES' alcoholometric table, 139.
freezing point of, 52, 53.
gases absorbed by, 54.
GAY-LUSSAC's tables, 123–131.
″ table for procuring a weaker alcohol of a certain strength from a stronger, 143, 144.
″ Do., abridged, 145.
Geneva spirit, 100–102.
GILL's platinum wire lamp, 55.
gin, 101, 102.
″ British, 101.
gin, cordial, 101.
″ substances used in preparing, 102-3.
grain, raw and malted, 58.
grains of paradise, 102.
grinding, 59, 60.
grist, proportions of, in mashing, 60, 61.
HASSAL's observations on the yeast plant, 68.
history of alcoholic liquors, 56, 57.
hollands, or geneva, 100, 102.
hydrometer, DICAS', 142.

ALCOHOL, *continued.*
hydrometer, Sykes', 132–134.
Indian stills, 114, 115.
iodoform, 55.
Ireland, revenue police of, 97.
juniper berries, 103.
lamp, 55.
Laugier's rum still, 110, 111.
lemon peel, 103.
liquorice, 103.
low wines, or singlings, 72, 99.
Löwitz' alcoholometric table, 131.
madder spirit, 116.
malt, proportion used, 63.
mash tun, 60.
mashing, 60–63.
methyle, 49.
milk spirit, 116.
Miller's still, 92, 94.
molasses, 106.
〃 fermentation of, 110.
Morewood's account of illicit distillation, 95, 97.
〃 account of the distillation of rum, 107.
must, 66.
mycoderma cerevisiæ, 68.
nectar, 57.
orange peel, 103.
orris root, 103.
Pereira's observations on yeast plant, 68.
Perrier's still, 75.
piment, 57.
Pistorius' still, 87–89.
platinum wire lamp, 55.
Poisonnier's modification of common still, 78.
potato beer, 113.
〃 spirit, 112, 113.
potteen distillery, account of, 94, 95.
properties of, 52–55.
〃 characteristic, 49.
propyle, 49.
prune tincture, 106.
raspberry brandy, 105.
〃 tincture, 106.
rectification of spirit, 98–103.
Richter's scale, 131.
rum, 106–112.
〃 distillation of, in France, 109.
〃 distillery, profits of, 109.
〃 stills, 107–108, 111.
rye, used instead of malt, 63.
saccharometer, 137.
Sharpe's still safe, 86.
Silbermann's dilatometer, 140–142.
singlings, or low wines, 72, 99.
smuggled whisky, 62, 63.
smuggling, anecdotes of, 96, 97.
soap in distillation, 72.
Soemmering's method of concentrating alcohol, 50.
Solimani's still, 80–82.
solvent properties of, 55.
sorbus aucuparia, spirit from, 117.
specific gravity of absolute alcohol, 52, 53.
spirits, British, 98.
〃 from carrots, 115, 116.
〃 geneva, 100–102.
〃 from Jerusalem artichoke, 114.
〃 from madder, 116.
〃 from milk, 116.
〃 new source of, 117.
〃 from potatoes, 112, 113.
〃 from potato-apples, 113.
〃 proof, 142.
〃 rectification of, 98–103.
〃 from rice, 114.
〃 yield of, from malt, 72.
〃 of wine, 50.
spiritous liquors, adulterations, 145, 146.
〃 〃 identity of, 99.
starch, conversion of into sugar, 62.
〃 transformation into dextrin, 71.
statistics of the spirit trade, 146–149.
still, Adam's, 78, 79.
〃 Alègre's 89–92.
〃 Berard's, 82.
〃 Canadian, 97, 98.
〃 Cingalese, 115.
〃 Coffey's, 75–77.
〃 common, 73.
〃 〃 improvement of, 74.
〃 Derosne's, 82–84.
〃 Dorn's, 87.
〃 Indian, 114, 115.
〃 Miller's, 92–94.
〃 Perrier's adaptation of, 75.
〃 Pistorius', 87–89.
〃 Poisonnier's, 78.
〃 rum, Laugier's, 110, 111.

ALCOHOL, *continued.*
still, Scotch, 72, 74, 75.
〃 Solimani's, 80–82.
〃 St. Marc's, 85, 86.
〃 safe, Sharpe's, 86.
sugar, products of, by fermentation, 67.
Sykes' hydrometer, 132–134.
Tralles alcoholometric tables, 118–122.
Turpin's observations on the yeast plant, 67, 68.
Ure's alcoholometric table, 135.
〃 improvement of Field's alcoholometer, 136, 137.
〃 table of boiling points, 136.
usquebaugh, 57.
vapour of alcohol, its elastic force, 54.
wash, specific gravity of, 62.
water, affinity of alcohol for, 53.
West Indies, rum stills used in, 107, 108.
whisky, 56, 57.
〃 excise laws, 63.
〃 old mode of levyiug duty, 74.
〃 potteen, 94, 95.
〃 smuggled, 62, 63.
〃 in Unit. States and Canada, 97.
wine alcohol, 49.
〃 spirit of, 50.
wood-spirit in alcohol, 146.
worts, 61.
〃 specific gravity of, after attenuation, 65.
〃 strength, regulated by excise, 62.
〃 temperature of, in fermentation, 65.
Woulfe's apparatus, 73.
yeast, artificial production of, 69, 70.
〃 composition of, 69.
〃 its mode of action, 67.
〃 plant, stages of growth, and microscopic appearance, 67–69.
〃 proportion used, 64.

ALUM—149–176.
alumina, 176.
alum-rock, 154.
alunite, 154.
ammonia alum, 153, 175.
boiling the lie, 162.
Castro (John Di), 149, 152.
Chaptal and Alban's process for preparing alum from clay, 169, 170.
Civita Vecchia alum works, 152.
commercial sulphate of alumina, 175.
composition of different alums, 150, 173.
crystallization of, 167.
cubic and octahedral, 173, 174.
evaporating basins, 162–164.
feather-alum, 157.
felspar, alum from, 170, 171.
from aluminous rocks, 169.
from clay, 169, 170.
hair-salt, 157.
history of, 149–152.
Hurlet and Campsie alum works, 163–166.
impurities in, 173.
isomorphism, 150.
liquors, 161.
lixiviation of the ores, 159–161.
as manure, 176.
manufacture of, 153–169.
natural alums, 150, 151.
neutral, 175.
old method of making, 153.
ores, lixiviation of, 159–161.
potassa alum, 153.
powder, preparation of, 164.
precipitation of, 164, 165.
produce of, 172.
production of, from the ore, 155.
〃 from clay, 169, 170.
〃 from alum stone, 154, 155.
〃 from felspar, 170, 171.
properties of, 153, 173.
Prussian blue, 175.
Richardson's patent process, 172.
roch alum, 149.
roching, 167, 168.
Roman, 155.
Scotch alum works, 158.
shales, 155–157.
slate, 152.
〃 ustulation of, 158, 159.
Spence's calcining process, 159.
Turner's process for preparing alum from felspar, 170, 171.
uses and applications, 176.
ustulation of alum-slate, 158, 159.
wavelite, 176.
Whitby alum works, 158.
Wiesmann's commercial alum, 175.
Wilson's patent process, 172.

AMMONIA—177–200.
amidogen, 183.
ammonium, 182.
〃 chloride of, 183–192.
from bituminous schist, 180.
from bones, 184–188.
Brewer's process for purifying sal-ammoniac, 193.
carbonate, 195–197.
chloride of ammonium, 183–192.
constitution of, 182, 183.
Crane and Julien's method of preparing carbonate of ammonia, 196.
Croll's patent process for the preparation of ammoniacal salts, 193.
Dalton's table of the strength of liquid ammonia, 181.
Davy's do., 181.
estimation of, 197–200.
furnace for distilling bones, 184, 185.
gaseous, 177, 178.
from guano, 180.
hartshorn, spirit of, 178.
Hompesch's patent for preparing ammonia from bituminous schist, 180.
impurities in, 182.
Kurtz, Cropper, & Co.'s sal-ammoniac manufactory, 188–192.
liquid, 178–183.
〃 how prepared in laboratory, 178.
〃 manufacture of, 179, 180.
〃 Laming's process, 181.
〃 Newton's process, 180, 181.
in nature, 177.
sal-ammoniac, 183–192.
〃 its preparation in Egypt, 184.
〃 from bones, 184–188.
〃 crystallization of, 190.
〃 its preparation from gas-liquor, 188–192.
〃 purification of, 193.
〃 its sublimation, 191, 192.
salts, ammoniacal, Croll's patent process for preparing, 193.
〃 〃 Laming's patent, 194, 195.
〃 〃 Spence's patent, 194.
〃 〃 from guano, 194.
〃 〃 from peat and urine, 194.
〃 〃 value of, 197.
sesquicarbonate of, 195–197.
sulphate of, 194, 195.
tables of strength of, from its specific gravity, 181, 182.
Watson's patent process for procuring ammoniacal liquor from gas-water, 180.

ANTIMONY—200–213.
its action with acids, 201, 202.
alcohol, 200.
applications of, 205.
assay of its ores, 212, 213.
Britannia-metal, 205.
bronzing salt, 209.
butter of antimony, 209.
compounds with negative elements, 205.
copper, antimonial, 201.
eliquation of the sulphide, 203–5.
estimation of, quantitative, 209–211.
flowers of, 208.
furnace for reducing the ores at one operation, 202.
golden sulphide of, 207.
importation of, 213.
kermes mineral, 206, 207.
manufacture of, 202–205.
oxysulphide, 207, 208.
preparation in the laboratory, 201.
properties of, 201.
Rose's process for separating antimony from tin, 211.
separation of, from arsenic, 212.
sources of, 201.
stereotype metal, 205.
sulphides, 205–208.
〃 eliqnation of, 203–205.
〃 reduction of, 211, 212.
terchloride, 209.
teroxide, 208, 209.
type metal, 205.
uses of, 205.

ARSENIC—213–222.
arsenic acid, 218.
arsenious acid, 214–218.
〃 composition of, 214.
〃 manufacture of, 216–218.
〃 properties, 214, 215.
〃 tests, 215.
〃 uses, 218.
arsenites, 219.

ARSENIC, *continued.*
compounds, native, 213.
estimation of, quantitative, 220–222.
green, Scheele's, 219.
" Schweinfurth, 220,
Levol's method of estimating, in alloy with copper and tin, 222.
manufacture of, 214.
Marsh's apparatus, 215, 216.
" Ure's modification of, 216.
orpiment, red, 218, 219.
poison tower, 217.
potassa, arsenite of, 219.
preparation in the laboratory, 213.
properties of, 214.
realgar, 218, 219.
Rose's process for separating antimony from arsenic, 221, 222.
Scheele's green, 219.
schliech or arsenical iron, 216.
Schweinfurth green, 220.
separation of from lead, tin, mercury, *et cetera,* 221, 222.

BALSAMS—222–235.
Balm of Gilead, 224.
balsamic ethers, 234, 235.
benzoin, 225, 226.
" analyses of, 226.
" Bombay, 226.
" Siam, 225.
" Sumatra, 225, 226.
Canada, 223.
copaiba, 223, 224.
divisions of, French and German, 222.
dragon's-blood, 227.
ethers, balsamic, 234, 235.
gum Benjamin, or benzoin, 225, 226.
Hernannez' account of Peru balsam, 228, 229.
liqnidambar, 227.
Mecca, or opobalsam, 224.
Monardes' account of Peru balsam, 228.
Myrospermum of Sonsonate, 230, 231.
Myroxilon peruiferum, 229.
opobalsam, 224.
paracopaiba oil, 224.
Peru, 228–234.
properties of, 222.
statistics, 235.
storax, 226, 227.
styracon, 234.
Tolu, 227, 228.

BEER—236–284.
adulteration of, 281.
ales, pale, 277–279.
" Scotch, 279.
alum, used in fining beer, 277.
analysis of, 281–284.
analysis of the water used in Messrs. Tennent's brewery, 278.
attemperator, 253–254, 274.
" Archimedean, 281.
barley, composition of, 242, 243.
" selection of, for brewing, 236.
Bate's saccharometer, 257, 258.
Bavarian beers, 273.
boiling the worts, 260–269.
boiling-copper, 264.
brewer's grains, composition of, 244.
brewing, 247–277.
Burton ales, 277, 278.
" water, 244, 245.
Casartelli's saccharometer, 260.
chemistry, importance of a knowledge of, in brewing, 236.
cleanliness essential in a brewery, 251.
cleansing, 275–277.
cocculus Indicus, 281.
" " test for its detection, 283.
coolers, 270.
cooling the worts, 269, 270.
Cook, Brothers' bitter ale, 278.
couch, malting, 237, 238.
Crockford's Archimedean attemperator, 280, 281.
Dring & Fage's saccharometer, 257, 258.
fermentation, 271–275.
" Bavarian method, 273, 274.
" chemical nature of, 273, 274.
" Harvie's apparatus, 274.
fermenting square, double, 274.
" " Walker & Son's, 274, 275.
fining liquor, 277.
flooring, 239.
gas-drying of malt, 240, 241.
grinding do. 247, 248.
hops, 245–247.
" action of boiling on, 263.
" analysis of, 245.

BEER, *continued.*
hops, bitter principle of, 246.
" Newton's mode of preparing the extract from, 263.
" oil of, 245, 246.
" proportion used for pale ales, 278.
" qualities of, 246, 247.
" selection of, 247.
" statistics, 247.
" table showing the quantity of hops per quarter of malt, 266–268.
" table showing the increase of hops for every degree from 50° to 75° Fahr., 269.
hop-converter, Tizard's, 263.
hordein, 243.
humulin, 263, 264.
isinglass, its use in fining beer, 277.
kiln-drying of malt, 239, 240.
Levesque's table of time, temperature, *et cetera,* in mashing, 254.
Long's saccharometer, 258.
lupulin, or bitter principle of hops, 246.
malt and malting, 236–242.
malt, exhaustion of, 249, 250.
" gas-drying, 240, 241.
malt-kiln, 240.
malt-mill, 248.
malting in Munich, 241.
malting apparatus, Tizard's, 241, 242.
malting-couch, 237, 238.
mash-tun, 252.
mashing, 248–257.
" attemperator, 253, 254.
" difference between vinegar-making, distilling, and brewing, 250.
" general imperfection of the methods followed, 250, 253.
" inexpediency of repeated mashings, 256, 257.
" Levesque's table of time and temperature, 254.
" principles of, 248–251.
" process of, 251, 252.
" setting the tap, 255.
" sparging, 257.
" temperature of, 254, 255.
" use of thermometer, 255, 256.
Newton's method of preparing the extract from the hop, 263.
oil of hops, 245, 246.
pale ales, 277–279.
picric acid, 282.
porter, 279, 280.
refrigerators, 270, 271.
saccharometer, Bate's, 257, 258.
" Casartelli's 260.
" Dring & Fage's, 257, 258.
" Long's, 258.
saccharometers, comparison of, 258.
saccharometrical tables, 258–260.
saccharometry, 257–260.
Scotch ales, 279.
sparging, 257.
spring beer, 236.
statistics, 284, 285.
steeping the grain, 237.
table showing the quantity of hops per quarter of malt, 266–268.
table showing the increase of hops for every degree from 50° to 75° Fahr., 269.
table of gravity of wort, 269.
Tennent's ale, 277, 278.
thermometer, use of in mashing, 255, 256
Tizard's hop-converter, 263.
Tizard's malting apparatus, 241, 242.
" mashing attemperator, 253, 254.
" saccharometrical table, 258, 260.
Wagner on oil of hops, 245, 246.
Walker & Son's fermenting square, 274.
water for brewing, 244.
" expansion of, by heat, 259.
wort, boiling of, 260–269.
" cooling, 269, 270.
" qualities of, 256.
" table of gravity of, 269.
" volume of, imbibed by hops, 269.

BENZOL—285–286
properties and preparation of, 285.
uses, 286.

BISMUTH—286–291.
alloys, 288.
analysis of its combinations, 290, 291.
basic nitrate, or pearl white, 289, 290.
eliquation of, 287, 288.
fusible metal, 288.
native combinations, 286.
nitrates, 289.

BISMUTH, *continued.*
oxides, 288, 289.
pearl white, or pearl powder, 289, 290.
rondelles, safety, 288.
ternitrate, 289.

BITUMEN—291–299.
of Abruzzi, 293.
of Cuba, 293.
from Dead Sea, 293.
applications of, 293–298.
artificial asphalt, 295, 296.
asphalt pavements, 294, 295.
asphaltene, 292.
asphalting, 296, 297.
" in France, 297, 298.
Barbadoes tar, 298.
bechelbronn, 292.
composition of, 292.
deposits of, 291.
mastic, uses of, 296.
mineral fat, 292.
" tar, 298.
naphtha, 298.
oil, rock, 298.
pavements, asphalt, 294, 295.
petrolene, 292.
petroleum, 291-92, 298.
purification of, 291, 292.
rock oil, 298.
tar, Barbadoes, 298.
" lake of Trinidad, 293.
" mineral, 298.

BLEACHING—299–327.
American process, 313.
antiquity of, and manner of bleaching previous to use of chlorine, 299, 300.
Bouchard's continuous system, 321.
Bridson's washing machine, 308, 309.
bucking, 304–306.
bucking-kier, 305, 306.
calendering, 318.
china-grass, 322.
chloride of lime, 300.
chlorine, 299–301.
chlorine gas, bleaching with, 310.
Claussen's bleaching process, 314.
" for bleaching linen, 320.
" flax-retting process, 319.
" for silk, 326.
continuous process, 321.
cotton, 300.
" fibres, 302.
" goods, impurities in, 302, 303.
" pod and flower, 300.
dash-wheel, 304.
flax, fibres of, 302.
" plant, 319.
" retting, 318, 319.
Graham's improved bucking-kier, 306.
Grean's bleaching process, 312, 313.
Higgins' do. do. 314.
hydro-extractor, centrifugal, 315.
immersion in the bleaching liquor, 311.
jute, bleaching of, 322.
Lawrie's improved bucking-kier, 305.
linen, 318–320.
liquor, 300.
madder work, bleaching for, 303.
machine for scouring woollen goods, 323.
mangling, 316.
Metz's pressure apparatus, 306, 307.
More & Son's water mangle, 316.
muslins, 314, 315.
paper, materials for manufacture, 326, 327.
powder, 300, 301.
" action of, 309, 310.
" liquefaction of, 311.
pressing apparatus, Metz's, 306, 307.
rags for paper, 327.
retting, flax, 318, 319.
second stage, 309.
silk, 325, 326.
souring, 309.
starching and drying, 317, 318.
straw, 326.
sulphuring silk goods, 325.
" woollen goods, 323–325
washing machines, 307–309.
water mangle, 316.
woollen goods, 322–325.

BLEACHING-POWDER—327–335.
calcium, oxychloride of, 328.
characteristics of, 332.
chloride of lime or bleaching powder, 327.
chlorine, combination of, with hydrate of lime, 331.
" from common salt, 331, 332.
" preparation of, 328.

BLEACHING-POWDER, *continued.*
chlorine still, 330.
chlorometry, 333–335.
composition of, Editor's experiments to elucidate, 327, 328.
DUNLOP's method of liberating chlorine from common salt, 331, 332.
FRESENIUS and WILL's method of testing manganese ore, 329.
lime, chloride of, 327.
″ combination of, with chlorine, 331.
″ preparation of, for bleaching-powder, 328.
liquor, apparatus for making, at Mulhouse, 332.
manganese, peroxide of, 329.
manufacture, 330–332.
oxychloride of calcium, 328.
preparation of the chlorine, 328.
″ of the lime, 328.
WELTER's test, 333.

BONE—335.

BONE-BLACK—335–342.
its absorption of lime, 338.
action on salts, 337.
animal charcoal, 335.
black, ivory, 339.
bones, calcination of, 338, 339.
charcoal, animal, 335
″ its decolorizing power, 336.
decoloration of sirups, new agent for, 342.
ivory black, 339.
kilns for calcining bones, 338.
lime, absorbed by animal charcoal, 338.
as manure, 341, 342.
PARKER's charcoal reburner, 340.
PONTIFEX and WOOD's do., 340, 341.
preparation of, 338, 339.
properties, 335–337.
purification of, 341.
revivification of, 339–341.
″ SCHATTEN's process, 339.
″ PARKER's reburner, 340.
″ PONTIFEX & WOOD's, 340.
ROMANET's investigations on animal black as a manure, 341, 342.
sirups, new decoloring agent for, 342.
substitutes for, 342.

BORACIC ACID—342–346.
analysis of the crude acid, 346.
BOWRING on the lagoons of Tuscany, 343.
composition of, 343.
evaporation, 345.
formation, theory of, 344.
manufacture of, in Tuscany, 343–346.
PAYEN's account of do., 343, 344.
preparation of, 342.
properties of, 342, 343.
statistics, 346.
test of, 343.
WITTSTEIN's analysis, 346.

BORAX—346–353.
adulterations of, 351.
biborate of soda, 346.
composition of, 346, 347.
estimation of, 350–352.
as a flux, 350.
granular, SAUTTER's patent, 350.
manufacture of, KOEHNKE's improved method, 349.
native, 347.
octahedral, 349.
oxides, metallic, dissolved by, 350.
preparation of, 347, 348.
properties, 346, 347.
refining of, 348, 349.
ROSÉ on estimation of boracic acid, 351.
SAUTTER's patent granular, 350.
soda, biborate of, 346.
statistics, 353.
tincal, or native borax, 347.

BREAD—353–392.
adulteration of, 385–392.
agriculture, importance of, 353.
alum in, 387–389.
″ tests of, 388, 389.
American flour, 366.
ammonia, sesquicarbonate of, 391.
analyses of grain, 354, 355.
apparatus, baking, 368, 369.
ash of Indian corn, 360.
″ of oats, analyses, 359.
″ of rice, 360.
″ of rye, 358.
″ of wheat, 356.
″ yielded by ground wheat, 354.

BREAD, *continued.*
assamar, 379.
assimilation in the body, 355, 356.
bakehouse, 374–376.
baking apparatus, 368, 369.
″ oven, 373, 374.
″ powder, 380.
″ process of, 369, 370.
barley, analysis of, 358.
″ and oats, analyses of, 359.
barm, German, 370, 371.
bean flour in, 387.
biscuit-baking, 381–384.
″ fancy, 383.
″ oven, SLATER's, 382.
BOLAND's method of testing flour, 385.
carbonate of ammonia in, 379, 380.
″ magnesia, 390.
″ soda, 380.
CLAYTON's kneading machine, 371.
cleaning and winnowing the grain, 361.
composition of fancy breads, 384.
copper, sulphate of, in bread, 390, 391.
corn, Indian, 359, 360.
crust, brown color of, 379.
DISDIER's kneading machine, 373.
DUMAS on bread adulterations, 391.
ergot of rye, 357.
fabrication of, 367.
fancy biscuit baking, 383.
″ biscuits, composition of, 384.
fermentation, 367, 368.
flour, American, 366.
″ BOLAND's method of testing, 385.
″ ROBINE's do. do. 386.
″ yield of, in bread, 377, 378.
flours, analyses of, 377.
food, its assimilation in the body, 355.
German barm, 370.
gluten, amount of, in wheat, 355.
″ crude, 354.
″ test of, in flour, 385, 386.
grain, composition of, 353, 354.
″ cleaning and winnowing, 361.
″ mills, 360–365.
GRANT's biscuit-baking apparatus, 381.
grinding, 362.
groats, 358.
gypsum in flour, 387.
hopper and bolter, 363.
HORSFORD's table of quantity of nitrogen in different kinds of wheat, 354.
hydrochloric acid in, 380.
Indian corn, 359, 360.
JOHNSTON's table of ash yielded by different samples of wheat, 354.
kneading machines, 371–373.
″ trough, 369.
leaven, 367, 368.
legislative regulations, 392.
lime-water in, 392.
machines for kneading, 371–373.
magnesia, carbonate of, in bread, 390.
maize, analyses, 360.
mills, 360, 365.
moistening of the grain, 365.
MOUCHOT's model bakehouse, 374–377.
nitrogen, per centage of, in different kinds of wheat, 354.
″ its use in food, 353.
nitrogenous bodies, 356.
oats, analyses of, 358, 359.
″ analyses of the ash of, 359.
oil of wheat, 354.
oven, baking, 373, 374.
″ biscuit, SLATER's, 382.
panary fermentation, 367, 368.
patent yeast, 370, 371.
piled, 370, 381.
plaster of Paris in, 387.
potatoes, use of, 370.
powder, baking, 380.
preparation of the corn, 360.
process of baking, 369, 370.
products of grinding, 366.
proportion of water in, 378.
rice, analyses of, 360.
ROBINE's method of testing flour, 386.
rye-flour, composition of, 357, 358.
″ starch, characteristics of, 386.
sesquicarbonate of ammonia, 390, 391.
SEWELL's patent for making bread with carbonate of soda, 380.
SLATER's biscuit oven, 382.
soda, carbonate of, in bread, 380.
starch, 355.
substitutes for yeast, 380.
sugar in flour, 355.
sulphate of copper in, 390, 391.
unfermented, 367, 379.
water, proportion used, 378.

BREAD, *continued.*
Weevil biscuit-baking factory, 382, 383.
weight of bread as delivered, 389.
″ loss of, when kept, 389.
wheat, analyses of, 357.
″ ash, analyses of, 356.
″ bran, analysis of, 355.
″ composition of, 354.
″ oil, per cent., 354.
″ per centage of ash, 354.
″ per centage of nitrogen in different kinds, 354.
″ superiority to other cereals, 378.
″ yield of, when ground, 366.
winnowing the grain, 361.
yeast, patent, 370, 371.
″ substitutes for, 380.
″ used in bread-making, 370.
yield of flour, 377, 378.

BROMINE—392–394.
analysis, 393, 394.
bittern, 392.
preparation of, 392, 393.
properties, 393.

BUTTER—394–404.
acid, butyric, 395.
″ lactic, 395.
adulterations, 404.
American butter-worker, 401.
analysis of milk, 395, 396.
butyric acid, 395.
churning, process of, 400.
churns, 397–400.
″ diagonal, TINDALL's, 398, 399.
″ double, RENNES', 399.
disadvantages of zinc vessels, 403.
fluorine in milk, 395.
historical notice, 397.
lactic acid, 395.
lactometer, 396.
milk, 394–397.
″ manufacturing uses, 396, 397
″ method of testing, 396.
packing, 401, 402.
preparation of, 397–403.
RENNES' double churn, 399.
salting, 401.
Scotch method of making, 402, 403.
sweet cream and milk, butter from, 402.
TINDALL's diagonal churn, 398, 399.
vegetals, butter from, 394.
yield of, from milk, *et cetera*, 402.
zinc vessels, disadvantages of, 403.

CANDLE—404–441.
acid, margaric, 408.
″ oleic, 409.
″ palmatic, 410, 411.
″ stearic, 407.
antiquity of wax candles, 405.
attraction, capillary, 417, 418.
bleaching of palmatic acid, 434, 435.
″ of stearic acid, 433.
″ of wax, 411, 412.
capillary attraction, 417, 418.
cerin, 412.
cerotin, 412.
cetin, 410.
coccus ceriferus, 411.
cocinin, 410.
coco-stearin, 410.
″ candles, 435.
composites, 435, 437.
dipped candles, 420–425.
dipping, 422–425.
fats, 405, 406.
″ of different animals, 413.
″ pressing machines, 431, 432.
″ purification of, 413–417.
″ saponification of, 430.
FONTAINEMOREAU's process for refining vegetal tallow, 435, 436.
glycerin, 406.
″ removal of, from fats, 430.
HEMPBELL and BLUNDELL's process for refining palmatic acid, 435.
hircin, 413.
historical notice, 404, 405.
KEMPTON's patent wicks, 418.
lard, hogs', 413.
machines, improved dipping, 423, 424.
″ moulding, 426–428.
″ pressing, 431, 432.
manufacture of, 420.
margaric acid, 408.
margarin, 407
materials used in the manufacture, 405–413.
melen, 412.

CANDLE, *continued.*
Morgan's moulding machine, 427, 428.
mould candles, 420, 425–429.
myricin, 412.
oleic acid, 409.
olein, 408, 409.
palm oil, 434.
palmatic acid, 410, 411.
" " bleaching of, 434, 435.
" " refining, 435, 436.
palmatin, 410,
" lights, 434.
Palmer's patent dipped candles, 425.
" patent wicks, 419.
paraffin, 412, 413.
" candles, 440, 441.
Price's process, 436–438.
purification of the tallow, 420, 421.
refining of palmatic acid, 435, 436.
saponification of fats, 430.
spermaceti, 409, 410.
" candles, 439, 440.
statistics, 441.
stearic acid, 407.
" " pressing, 431, 432.
stearin, 406, 407.
" and stearic acid candles, 429–434.
suet, mutton, 413.
Sykes' patent wick-making machine, 419.
tallow, 413.
" machine for chopping, 414.
" purification of, 413–417, 420, 421.
tapers, wax, 439.
Tilghmann's patent process, 433, 434.
wax, 411, 412.
" bleaching of, 411.
" from vegetals, 411.
" candles, 438, 439.
whiteness and hardness, receipts for producing, 429.
wicks, 417–420.
" machine for cutting, 421, 422.
" machine for making, 419, 420.
Young's paraffin process, 440.

CAOUTCHOUC—441–452.
applications of, 443.
Burke's improved method of vulcanizing, 449.
caoutchoucin, 451.
combination of, new, 450.
composition of, 442, 443.
condensation, 443, 444.
cutting into sheets, 444.
deodorizing caoutchouc fabrics, 448.
distillation of, 450, 451.
Dumas' suggestion for dissolving caoutchouc in ether, 446.
fabrics, waterproof, 446, 447.
Gerard's caoutchouc solution, 447.
glue, marine, 452.
Goodyear's vulcanizing process, 448.
" new combination of, 450.
Hancock's vulcanizing apparatus, 449.
heveen, 451.
juice, 442, 443.
" Norris' method of importing, 447.
Lorimer's process for purifying and condensing caoutchouc, 444.
Mackintosh cloth, 446.
manufacture of, 443.
" of caoutchouc thread, 444.
" of round thread, Aubert and Gerard's, 445, 446.
marine glue, 452.
Moulton's improved vulcanizing process, 450.
Nickel's do., 449.
Norris' method of importing caoutchouc juice, 447.
preparation of, 442.
products of, by distillation, 451.
properties, 442.
purification and condensation, 443, 444.
solvents of, 446, 447.
source of, 441.
statistics, 452.
still, 451.
sulphuration of, 448.
tar, its combination with, 450.
thread, caoutchouc, 444–446.
tree, 441.
Varrac's method of deodorizing caoutchouc fabrics, 448.
vulcanizing, 448, 449.
" improvements in, 449, 450.
waterproof fabrics, 446, 447.

CEMENT—452–463.
acid, silicic, 459.
alkalies in, 459, 460.

CEMENT, *continued.*
alumina, 459.
beton, 461.
Booker's lime-kiln, 454.
building, 453–456.
clays, 459.
concretes, 453, 461.
diamond, 452.
estimation of, 460.
gypsum, or plaster of Paris, 462.
hydraulic, 456.
" limestones, 457, 459.
iron-pipes, cement for connecting, 453.
Keene's, 462.
lime, 453.
" burning, 453–455.
limestones, hydraulic, 457–459.
magnesia, 459.
Martin's, 462.
miscellaneous, 452.
mortar, 455.
" Turkish, 462, 463.
mosaics, 462.
Mulgrave, 460, 461.
Parian, 462.
Parker's, or Roman cement, 460, 461.
plaster of Paris, 462.
Portland, 460, 461.
puzzolana, 460, 461.
resinous, 452.
Roman, 460, 461.
Rudersdorf's lime-kiln, 454, 455.
sand for mortar, 455, 456.
silicic acid, 459.
Singer's 453.
stucco, 462.
trass, 461.
Varley's, 453.

CHEESE—463–470.
adulteration of, 470.
analysis of, 469.
casein, 468.
cheddar, 467.
chessart, or cheese-vat, 464.
coloring of, 468.
composition of, 468, 469.
cream cheese, 468.
curd breaker, 464.
" cutter, 464.
Gruyere, 467.
Neufchatel, 468.
Parmesan, 467.
potato cheese. 468.
preparation of, 463.
press, 464, 465.
properties, 469, 470.
runnet, 463.
skimmed milk cheese, 465, 466.
statistics. 470
Stilton, 467.
sweet milk cheese, 468.
turner, 466, 467.
utensils used in making, 464.

CHLOROFORM—470–473.
adulterations of, 471–473.
alcohol, detection of, 472.
aldehyde, 472.
anæsthetic effects of, 471.
composition of, 471.
densimeter, 472, 473.
manufacture of, 471.
methyl, compounds of, 472.
properties, 470, 471.

CIDER—473–477.
adulteration of, 476, 477.
apples, 473, 474.
" composition of, 473.
" crushing, 474.
" pressing, 474, 475.
bottling, 475, 476.
fermentation, 475.
lead in cider, 476, 477.
pears, analysis of, 476.
perry, 476.
preparation of, 474.
properties, 476.

CITRIC ACID—477–481.
action of heat on, 478.
adulteration of, 480, 481.
composition of, 477.
Firmin & Son's manufactory, 479, 480.
heat, its action on citric acid, 478.
lemon juice, analysis of, 478.
manufacture of, 478–480.
sources of, 477.
statistics, 481.
uses of, 480.

COBALT—481–493.
adulteration of, 492, 493.
antiquity of, doubtful, 481.
arsenical cobalt, 482, 483.
azure, 484.
blue, cobalt, improved processes, 489.
" Thenard's, 482.
crucibles for melting the smalt, 486.
eschel, 484, 487, 489.
estimation of, quantitative, 491, 492.
farbe, 484, 487.
fluxes for the ores, 485.
furnace for melting cobalt glass, 486.
fusion of the smalt, 486, 487.
glance, 483.
glass, 486.
grinding and washing the smalt, 487, 488.
inks, sympathetic, 482.
manufacture of, 483.
ores, 482, 483.
oxides of, 483.
poison gallery, 484.
preparation of, 481, 482.
properties, 482.
pyrites, 483.
roasting, 484, 485.
schliech, 484.
separation of cobalt from copper ores by Vivian's patent, 490, 491.
smalt, 483–489.
" adulteration of, 492, 493.
" analysis of, 492.
" uses, 488, 489.
speiss, 485.
statistics, 493.
streublau, 484, 487.
test, infallible, of its presence, 482.
Thenard's blue, 482.
ultramarine, 484.
Vivian's improvements in obtaining nickel and cobalt, 490, 491.
zaffre, 489.

COPPER—493–532.
assaying of copper ores, 498–500.
" furnace, 498.
azurite, 495.
Birkmyre's smelting process, 516, 517.
black oxide of, 495.
blistered copper, 513.
Brankart's smelting process, 515.
carbonates of, 495.
combinations of, native, 494.
Davies' smelting process, 516.
De Sussex's do. do. 517.
dressing of the ores, 497, 498.
estimation of, 525–528.
fourneau à manche, 519.
furnace for assaying, 498.
furnaces, smelting, 501, 504, 508.
" " foreign, 521–524
gahrrost, 522.
grey, 495.
historical notice, 493, 494.
Low's smelting process, 517.
malachite, 495.
manufacture of, 497–524.
mine, copper in the, 495, 496.
Napier's smelting process, 516.
native combinations of, 494.
ores, smelting of, 501, 524.
oxides of, 495.
Parkes' smelting process, 517.
preparation of pure copper, 496.
properties of, 497.
purple copper, 494.
pyrites, 494, 495.
red oxide, 495.
Rivot & Phillips' smelting process, 515.
rolling, 524, 525.
smelting, 501–524.
" foreign methods of, 519–524.
" patented improvements, 515, 518.
statistics, 528–532.
sulphide, 494.
Trueman and Cameron's smelting process, 517, 518.

COPPER ALLOYS—533–553.
alloys in general, nature of, 533, 534.
analysis of, 553.
arcot, 537.
argentan, 540, 541.
bell-metal, 550.
brass, 534–540.
" antiquity of, 534, 535.
" foundry, furnaces used, 537, 538.
" varieties of, 535, 536, 539.
" wire, 536.
British plate, 540, 541.

COPPER ALLOYS, *continued.*
  bronze, 541.
    " antique, 545.
    " gravity of, 541.
    " tempering, 542.
    " varieties, 543.
  calamine, analysis of, 537.
  cannon metal, 545–550.
    " furnaces for casting, 537, 538.
  coins and medals, 543–545.
  copper coins, standard weights, legal tender, *et cetera*, 545.
  cymbal and tam-tam metal, 551.
  electrum, 540.
  furnaces used in brass-founding, 537, 538.
    " " cannon-founding, 547–550.
  German silver, 540, 541.
  gilding-metal, 535.
  Mannheim gold, 535.
  medals in bronze, 543–545.
  moulds for cannon, 546, 547.
  nature of alloys in general, 533, 534.
  ordnance or cannon metal, 545–550.
  pakfong, 540.
  pinchbeck, 535.
  Proust's experiments on tinned vessels, 552.
  Rupert's metal, 535.
  silver, German, 540, 541.
  telescope or speculum metal, 551.
  tinning of vessels, 551–553.
  tutenag, 540.
  wire-brass, 536.

COPPER SALTS—553–556.
  blue vitriol, 555.
  carbonate, 554.
  cupreous poisons, antidotes for, 554.
  oxide, 554.
  sulphate, or Roman vitriol, 555, 556.
  verditer, 554, 555.

DISINFECTANTS—556–565
  antiseptics, 556, 559, 560.
  aromatic substances, 564.
  artificial, 562–565.
  bleaching powder, 564.
  causes of infection, 558, 559.
  charcoal, 563.
  chlorine, 564.
  chloroxide of calcium, 564.
  cold, 562.
  Davy's method of ventilation, 561.
  definition of, 556.
  deodorizers, 556.
  embalming, 556, 557.
  gases absorbed by charcoal, 563.
  heat, 562.
  historical notices, 556–558.
  infection, causes of, 558, 559.
  light, its sanitary effect, 562.
  magnesia and lime, mixed sulphate of, 565.
  manganese, chloride of, 564.
  natural, 561, 562.
  od and odyl, 562.
  quarantine, 561.
  Reid's methods of ventilation, 561.
  respirator, Stenhouse's, 563.
  soil, 562.
  sulphurous acid, 565.
  tannic acid, 563.
  vampires, 558.
  ventilation, 560, 561.
  water, 562.

DYEING & CALICO-PRINTING—565–781.
  acacia catechu, 574.
  acid, alizaric, 608, 609.
    " anchusic, 569.
    " anilic, 596.
    " anthranilic, 597, 598.
    " arsenious, 643.
    " carminic, 577.
    " carthamic, 625.
    " carthamous, 625.
    " chlorisatinic, 595.
    " chrysanilic, 597.
    " ellagic, 582.
    " gallic, 581, 582, 629–632.
    " hyposulphoindigotic, 593.
    " indigotic, 596.
    " isatinic, 595.
    " melanogallic, 583.
    " melanotannic, 583, 584.
    " metagallic, 583.
    " nitrococcusic, 577.
    " nitropicric, 596, 597.
    " nitrosalicylic, 596.
    " paraellagic, 583.
    " pectic, 721, 728.
    " pyroalizaric, 608, 610.

DYEING & CALICO-PRINTING, *continued.*
  acid, pyrogallic, 582, 583.
    " sulphindigotic, 593.
    " sulphindylic, 593.
    " sulphopurpuric, 594.
    " tannic, 581, 629–632.
    " valerianic, 598.
  adulteration of madder, 618–621.
  affinity, elective, among coloring matters, 622.
  alizaric acid, 608, 609.
  alizarin, 606–608, 613–615.
  alkalies, action of, on indigo, 597, 598.
  alkanet, 569.
  alkermes, 599.
  aloes, 569, 570.
  aloetin, 569.
  Alsatian madder, 604.
  alum, 642.
    " plumb tub, 642.
  aluminous mordants, 769–773.
  American dye-stuffs, 566.
  anchusa tinctoria, 569.
  anchusin or anchusic acid, 569.
  anilic acid, 596.
  anilin, 598, 599.
  annotta, 570.
  anthranilic acid, 597, 598.
  archil, 570, 571.
  argol, 649.
  army cloth, 638.
  arsenic, 642, 643.
  arsenious acid, 643.
  arseno-stannate of soda, 655, 656.
  aryana, 575.
  attraction of organic fibres for coloring matters, 626.
  Avignon madder, 604, 605.
  barberry root, 571.
  barwood, 572, 573.
    " spirit, 653.
  bastard saffron, 624.
  benzidam, 599.
  benzidin, 599.
  berberin, 572.
  berberis vulgaris, 571
  berries, French, 579.
  bibromisatin, 596.
  bichlorisatin, 595.
  bignonia chica, 575.
  bixa orellana, 570.
  bleaching powder, tests of, 613.
  blue, prussian, 648, 649.
  Bolley's indigo test, 589.
  Brazil wood, 573, 574
  braziléin, 573.
  brazilin, 573.
  bromisatin, 596.
  buccinum, 566.
  busquets, 585.
  cactus coccinilifera, 575.
  cæsalpinia crista, 573.
  Calico-Printing, 679–757.
    acid, chromic, as a discharger, 748.
    ageing, 710.
    apparatus, 683–700.
      " steaming, 739–742.
    bandana printing, 746.
    bleaching, 706.
    block-printing by hand, 683–685.
      " by machinery, 688–692.
    blue, China, 749–751.
    bran, clearing with, 733–735.
      " fixing, 716.
    bubulin, 715.
    calendering, 706, 707.
    chalis, 754–757.
    chalk, its action on dye-baths, 727, 728.
    chemical resists, 743, 744.
    China-blue style, 749–751.
    chlorine, as a discharger, 745, 746.
    chromic acid, as a discharger, 748.
    cleansing liquor, 711, 716.
    clearing, 729–735.
    cloth, preparation of, 705–707.
    color-holders, improved, 686–688.
    colors, preparation of, 700–705.
    copperplate-printing, 692, 693.
    cotton and wool, mixed, 753, 754.
    cow-dung, analysis of, 711.
    cylinder machines, 694–698.
    cylinder-printing, 568, 693–699.
    cylinders, mode of engraving, 693, 694.
    damping, 707.
    delaines, 753, 754.
    discharge style, 745–749.
    drying arrangements, 699.
      " and ageing, 710.
    dung, substitutes for, 711, 712, 716–718.
    dunging, 710–718.
    dyeing, in madder style, 718–729.

DYEING AND CALICO-PRINTING.
  Calico-Printing, *continued.*
    enlevage style, 748.
    gas singeing, 706.
    Graham's patent fixing processes, 742.
    historical notice, 680–683.
    hot-flue, 699, 700.
    hot-plate singeing, 705.
    introduced into Europe, 568.
    lapis or lazulite style, 744.
    machine, padding, 736.
    madder, 720, 721.
    madder-bath, temperature of, 724, 725.
      " influence of foreign bodies on, 725–728.
    madder-style, 709–735.
    maddering, 718.
    mandarining style, 755–757.
    mechanical resists, 743.
    mineral colors, dischargers for, 749.
    Monteith & Co.'s discharging machine, 747.
    mordants, dischargers for, 748.
      " preparation of, 700–705.
      " printing of, 709.
    mule machine, 568
    neutral style, 744.
    organic coloring matters, dischargers for, 745, 746.
    padding machine, 736.
      " style, 735–737.
    perrotine, 690–692.
    plate-printing, 692, 693.
    press-printing, 689, 690.
    printing of woollens, silks, and mixed stuffs, 752–757.
    printing-rooms, 707, 708.
    processes, 708.
      " amaranth, for delaines, 754.
      " blacks, steam, 743.
      " blue, for delaines, 754.
      " " for silks, 755.
      " " for woollens, 753.
      " " prussian, 737.
      " " steam, 742.
      " chrome-green, 737.
      " " yellow, 737.
      " greens, steam, 742.
      " lemon, light, 737.
      " reds, steam, 742.
      " " for silks, 755.
      " " for woollen stuffs, 753.
      " violet, steam, 742.
      " yellows, steam, 742.
      " " for silks, 755.
      " " for woollens, 753.
      " " Turkey, for delaines, 754.
    resist or reserve style, 743–745.
    rongeant style, 748.
    sightenings, 705.
    silk stuffs, printing of, 754–757.
    singeing, 705, 706.
    soap, its action in clearing, 730 731.
      " stannic, 731.
    spirit colors, 738.
    statistics, 780, 781.
    steam-colors, 738–743.
    style, china-blue, 749–751.
      " discharge, 745–749.
      " enlevage, 748.
      " lapis or lazulite, 744.
      " madder, 709–735.
      " " for silks, 755.
      " mandarining, 755–757.
      " neutral, 744.
      " padding, 735–737.
      " resist or reserve, 743–745.
      " rongeant, 748.
      " topical, 737–743.
    styles, principal, enumerated, 708.
      " combination of, 751, 752.
    substitutes for dung, 711, 712, 716–718.
    surface-printing, 568, 689.
    tearers, mechanical, 687.
    temperature of madder-bath, 724, 725.
    thickenings, 700–705.
    topical style, 737–743.
    union machine, 568.
    viscosimeters, 704, 705.
    water, 721, 722.
    wool and cotton, mixed, 753, 754.
    woollen stuffs, printing of, 752, 753
  camwood, 574.
  carajuru, 575.
  carméin, 576, 577.
  carmin, 576, 578.
  carminic acid, 577.
  carthamic acid, 625.
  carthamous acid, 625.
  carthamus, 624.

DYEING & CALICO-PRINTING, *continued.*
catechu, 574, 575.
catechuic acid, 575.
chica, 575.
chlorisatin, 595.
chlorisatinase, 595.
chlorisatinese, 595.
chlorisatinic acid, 595.
chrome, 643.
〃 dyeing recipes for, 644, 645.
chromium, 643–645.
chrysanilic acid, 597.
chrysorhamnin, 579.
clearing, see *Turkey-red* and *Madder style.*
coccigranum, 599.
coccinellin, 576.
coccus cacti, 576.
〃 *ficus,* 600.
〃 ilicis, 599.
cochineal, 575–579.
colorimeter, 588.
colorin, 606, 616.
coloring matters, attraction of organic fibres for, 626.
〃 〃 mineral, 642–656.
〃 〃 organic, 569–636.
〃 〃 theory of fixation of, 757–768.
copper salts, 645, 646.
copperas, selection of, 646.
copperas, white, 656.
cotton vat, 641.
CRUM'S theory of fixation of colors, 760.
crystallin, 598.
crystals of tin, 651.
cudbear, 570.
curcuma longa, 632
curcumin, 633.
cutch, Malabar, 574.
cyanol, 598.
D'APLIGNY on the fixation of colors, 758.
degraissage, see *Turkey-red.*
divi divi, 632.
dripping-vat, 586.
DUNN'S patent for utilizing waste acetate of copper, 646.
dyebecks, 719, 720.
DYEING RECEIPTS *for* 10 *lbs. cotton,* 5 *lbs. silk, and* 10 *lbs. woollen.*
〃 adelaide, or light purple, on cotton, 661, Nos. 32, 33.
〃 black on silk, 662, No. 1.
〃 black on woollen, 665, No. 1.
〃 black for 5 lbs. woollen, 645.
〃 black on cotton and woollen, 667.
〃 black on cotton and woollen, by one process, 667.
〃 black on silk and woollen, by one process, 667.
〃 black on cotton, silk, and woollen, by one process, 667.
〃 black, blue, on cotton, 659, No. 3.
〃 black, blue, on silk, 662, No. 4.
〃 black, common, on cotton, 659, No. 1.
〃 black, deep hat, on silk, 662, No. 5.
〃 black, French, on silk, 662, No. 3.
〃 black, full deep, on silk, 662, No. 2.
〃 black, jet, on cotton, 659, No. 2.
〃 blue, logwood, on cotton, 660, No. 21.
〃 blue, Napoleon, on cotton, 648.
〃 blue, pigeon, on cotton, 666, No. 13.
〃 blue, royal, on cotton, 648.
〃 blue, royal, on silk, 648.
〃 blue, royal, on woollen, 648.
〃 blue, sky, on cotton, 647.
〃 blue, sky, on silk, 648–663, No. 20.
〃 blue, sky, on woollen, 666, No. 12.
〃 *blue and orange,* on cotton and woollen, 667.
〃 brown, on silk, 662, Nos. 6, 7.
〃 brown, on woollen, 665, Nos. 2, 3.
〃 brown, for 5 lbs. woollen, 645.
〃 brown, bronze, on silk, 663, No. 11.
〃 brown, catechu, on cotton, 659, No. 9.
〃 brown, chocolate, do., 659, No. 11.
〃 brown, chocolate, on silk, 663, No. 10.
〃 brown, cinn., on cotton, 659, No. 6.
〃 brown, fawn, do., 659, No. 8.
〃 brown, mordant, do., 659, No. 5.
〃 brown, red, on silk, 663, Nos. 8, 9.
〃 brown, spirit, on cotton, 659, No. 4.
〃 brown, uvanterin, do., 659, No. 7.
〃 brown, yellow, rich, on 5 lbs. woollen, 645.
〃 buff, on cotton, 648.
〃 buff, on silk, 664, No. 28.
〃 chocolates, catechu, 659, No. 10.
〃 crimson, on cotton, 660, No. 17.
〃 crimson, on silk, 663, No. 17.
〃 crimson, on woollen, 665, No. 4.

DYEING AND CALICO-PRINTING,
DYEING RECEIPTS, *continued.*
〃 crimson, on silk, 663, No. 13.
〃 drab, on cotton, 661, Nos. 40, 42
〃 drab, on silk, 664, No. 31.
〃 drab, on woollen, 666, No. 22.
〃 drab, on 5 lbs. woollen, 645.
〃 drab, on cotton, silk, and woollen, by one process, 667.
〃 drab, brown, on woollen, 666, No. 21.
〃 drab, catechu, on cotton, 662, No. 45.
〃 drab, green, on 5 lbs. woollen, 645.
〃 drab, olive, on cotton, 661, No. 41.
〃 drab, stone, on woollen, 666, No. 22.
〃 drab, yellow, on silk, 664, No. 30.
〃 fawns, catechu, on cotton, 659, No. 12, 660, Nos. 13, 14.
〃 flesh color, on silk, 664, No. 28.
〃 gold color, on silk, 664, No. 27.
〃 green, on silk, 665, Nos. 33, 34.
〃 green, on woollen, 666, No. 15.
〃 green, on cotton-yarn, silk, and woollen, 580.
〃 green, apple, on woollen, 666, No. 14.
〃 green, bottle, on cotton, 660, No. 27.
〃 green, do., on silk, 665, Nos. 36, 37.
〃 green, do., on 5 lbs. woollen, 645.
〃 green, chrome, on cotton, 644.
〃 green, fast, on woollen, 666, No. 16
〃 green, invis., on 5 lbs. woollen, 645.
〃 green, pea, on silk, 665, No. 35.
〃 green, sage, on cotton, 660, No. 26.
〃 green, with bark, 624.
〃 green, with bark, on cotton cloth, 660, No. 23.
〃 green, with fustic, on cotton cloth, 660, No. 24.
〃 green, with fustic, on cotton yarn, 660, No. 22.
〃 green, with prussian blue, on cotton, 660, No. 25.
〃 *green and pink,* on cotton and woollen, 667.
〃 *green and crimson,* on cotton and woollen, 667.
〃 iron-buff, on cotton, 647, 684,
〃 lavender, on cotton, 661, No. 35.
〃 lavender, on cotton, with safflower, 661, Nos. 38, 39.
〃 lavender, on silk, 664, Nos. 21, 22.
〃 leghorn, on cotton, 660, No. 19.
〃 lemon color, on cotton, 644.
〃 lilac, on cotton, 661, Nos. 30, 31.
〃 lilac, on cotton, with logwood, 661, Nos. 36, 37.
〃 lilac, on silk, 664, No. 23.
〃 maroons, on silk, 663, No. 19.
〃 nankeen, or iron buff, 647, 648.
〃 nankeen, on silk, 664, No. 28.
〃 olive, or bottle green, on cotton, 660, No. 27, 661, Nos. 28, 29.
〃 olive, on silk, 665, No. 38, 39.
〃 olive, on woollen, 666, No. 17.
〃 olive, on 5 lbs. woollen, 645.
〃 orange, on cotton, 660, No. 20.
〃 orange, on silk, 664, No. 29.
〃 orange, on woollen, 666, No. 11.
〃 peach, or lavender, on cotton, 661, Nos. 35, 38, 39.
〃 peach, on silk, 664, Nos. 21, 22.
〃 pink on silk, with safflower, 626, 632, No. 12., with coch., 663, No. 15.
〃 pink, on woollen, 666, No. 9.
〃 puce, on cotton, 661, Nos. 30, 31.
〃 puce, with logwood, 661, Nos. 36, 37
〃 puce, on woollen, 666, No. 20.
〃 purple, on cott., 661, Nos. 32, 33, 34.
〃 purple, on 5 lbs. woollen, 645.
〃 red, on cotton, 660, No. 15.
〃 red, on silk, 663, No. 14.
〃 red, on woollen, 600–665, No. 6.
〃 red, claret, on woollen, 665, No. 7.
〃 red, with barw., on cott., 660, No. 16.
〃 red, with sumach, on cotton, 629.
〃 rose-color, with saffl., on cotton, 626.
〃 rubys, on silk, 663, No. 19.
〃 salmon-color, on silk, 564, No. 28.
〃 scarlet, on cotton, 626.
〃 scarlet, on silk, 663, No. 18.
〃 scarlet, on woollen, 665, No. 5.
〃 scarlet, with coch., on silk, 663, No. 16.
〃 scarlet, with lace, on wool, 666, No. 8.
〃 scarlet, on wool and silk, 579.
〃 slate-color, on silk, 664, No. 32.
〃 slate-color, on woollen, 666, No. 23.
〃 stone-color, on cotton, 661, No. 43.
〃 stone-color, on silk, 664, No. 32.
〃 stone-drab, on cotton, 662, No. 44.
〃 straw-color, on silk, 664, No. 27.

DYEING AND CALICO-PRINTING.
DYEING RECEIPTS, *continued.*
〃 straw, light, on cot., 644, 660, No. 18.
〃 violet, on silk, 664, No. 23.
〃 violet, light, on woollen, 666, No. 19.
〃 white, French and pearl, on silk, 664, Nos. 24, 25.
〃 wine-color, on silk, 664, No. 23.
〃 wine-color, on woollen, 666, No. 18,
〃 yellow, on cotton, 623, 644.
〃 yellow, on silk, 633, 664, No. 26.
〃 yellow, on woollen, 666, No. 10.
〃 yellow, on 5 lbs. woollen, 645.
〃 yellow, on cott., silk, and wool., 635.
dyestuffs, imported and exported, 779.
ellagic acid, 582.
erythrin, 571.
erythrizlin, 571.
ferruginous mordants, 773–777.
fixation of coloring matters, 757–768.
flavetin, 623.
flavin, 623.
French berries, 579.
fustet, 579.
fustic, 579, 580.
〃 young, 579, 629.
fustin, 579.
gallic acid, 581, 582, 629–632.
galling, see *Turkey-red.*
galls, 580–582.
garancin, 606, 616, 617, 721
German vat, 639, 640.
grain colors, 600.
hæmatéin, 602.
hæmatin, 601.
hæmatoxylin, 601, 602.
hæmatoxylum campechianum, 601.
HELLOT'S theory of fixation of colors, 758.
historical notice, general, 565–568.
hyposulphoindigotic acid, 593.
Indian madder, 621.
Indian vat, 639.
indigo, 566, 567, 584–599.
〃 action of alkalies on, 597, 598.
〃 blue, 586, 591-593.
〃 composition of, 592.
〃 tests of, 588–591.
〃 varieties of, 587.
〃 vats, 636–642.
〃 white, 586, 592, 593.
indigofera, 584.
indigotic acid, 596.
iron mordants, 773–777.
〃 salts, 646.
〃 〃 dyeing recipes with, 647, 648.
isatin, 594–596.
isatinate of silver, 595.
isatinic acid, 595.
isatis sativa, 633.
isatis tinctoria, 584.
isatyd, 595.
JULIAN'S patent process for extracting the coloring properties of madder, 617, 618.
Johannisblut, 599.
kermes, 599, 600.
khair-tree, 574.
kinching, 658.
KUHLMANN'S experiments on pyroxilized tissues, 766–768.
KURTY'S patent for the preparation of madders and munjeet, 618.
kyanol, 598.
lac, 600.
〃 spirit, 600.
lead salts, 648.
lecanora, 570.
lecanorin, 571.
LEESHING'S patent for quercitron, 623.
lemon color, 644.
lichens, 571.
Lima wood, 573.
liquor, red, 642.
litmus, 570.
lizari, 603.
logwood, 566, 601–603.
luteoléin, 633.
luteolin, 623.
MACQUER on the fixation of colors, 759.
madder, 603–620, 720, 721.
〃 adulteration of, 618–621.
〃 Alsatian, 604.
〃 Avignon, 604, 605.
〃 colorin, 606.
〃 coloring principles of, 606–614.
〃 composition of, 605.
〃 flowers of, 618.
〃 Indian, 621.
〃 lizari, 603.
〃 *mulle,* 603–605.
〃 Palus, 604.

DYEING AND CALICO-PRINTING.
Dyeing Receipts, *continued.*
madder, preparation of, 603.
" purple, red, orange, yellow, and brown, 605, 606.
" spirit, 617, 618.
Malabar cutch, 574.
manganese, 648.
melanogallic acid, 583.
melanotannic acid, 583, 584.
metagallic acid, 583.
mimosa catechu, 574.
mineral colors, application of, 568, 569.
" dyes and mordants, 642-656.
mordant, red, 771, 772.
mordants, aluminous, 769–773.
" ferruginous, 773–777.
" principles of the action of the most important, 768.
" stanniferous, 650-656, 776–779.
" tartar, 649, 650.
" white copperas, 656.
moréin, 580.
morin, 580.
morinda citrifolia, 627.
morindin, 627, 628.
morus tinctoria, 579, 580.
mulle madder, 603–605.
munjeet, 621.
myrobalans, 632.
nerium tinctorium, 584.
nitrococcusic acid, 577.
nitropicric acid, 596, 597.
nitrosalicylic acid, 596.
oiling, see *Turkey-red.*
orcéin, 571.
orcin, 571.
organic coloring matters, 569-636.
pallampoors, 567.
Palus madder, 604.
paraellagic acid, 583.
pastel, 634.
" vat, 636–639.
peach-wood, 573.
pectase and pectose, 582.
pectic acid, 612, 721, 728.
pectin, 582.
Penny's indigo test, 589.
Pernambuco, 573.
Persian berries, 579.
Persoz's views on the fixation of colors, 760–765.
phenicin, 594.
pittacal, 621.
Plichtho's art of dyeing, 566.
Pliny's account of topical dyeing in ancient Egypt, 567.
plumb spirit, 654.
potassa, bichromate of, 643–645.
" bitartrate of, 649.
" vat, 639.
Practical Operations, 656–659.
to prepare annotta, 656.
to prepare catechu, 656.
to make sulphate of indigo, 656.
to make red liquor, 656.
to make caustic potassa, 657.
to make caustic soda, 657.
to make lime-water, 657.
to make bleaching liquor, 657.
to make a sour, 657.
to make cochineal liquor or paste, 657.
to make iron liquor, 657.
to make up a blue vat, 657.
to make spirits or tin preparations, 657.
to make copperas solution, 657.
to make solutions of blue-stone or sulphate of copper, 657.
to remove oil stains, 657.
to remove iron stains, 657.
to remove mildew from cotton, 657.
to remove indelible ink-marks, 657.
to detect animal and vegetal fibres, 658.
to detect mixed fabrics of cotton and wool, 658.
to detect cotton in linen, 658.
to detect do., another method, 658.
to detect cotton and wool, 658.
to detect cotton with silk and wool, 658.
to detect do., another method, 658.
to preparé cotton yarn for dyeing, 658.
to prepare cotton cloth for dyeing, 658.
See also Dyeing Receipts.
prussian blue, 648, 649.
prussiate, red, 642.
" yellow, 642.
pterocarpus santalinus, 626.
purple, Tyrian, 566.
pyroalizaric acid, 608, 610.
pyrogallic acid, 582, 583.

DYEING & CALICO-PRINTING, *continued.*
pyroxilized tissues, 766–768.
queen-wood, 573.
quercitréin, 622.
quercitrin, 621, 622.
quercitron, 621–624.
quercus infectoria, 580.
quercus nigra, 621.
receipts, 659–667.
red liquor, 642.
" mordant, 771, 772.
" spirits, 653.
" Turkey, 567, 668–679.
redoul, 579.
reseda luteola, 633.
resin, alpha, 612.
" beta, 612.
rhamnéin and rhamnin, 579.
rhamnus, 579.
rhus coriaria, 629.
" *cotinus*, 579.
" *myrtifolia*, 579
roccella, 570.
rodou, 579.
rot steep, 658.
rubia munjista, 621.
" *tinctorum*, 603.
rubiacic acid, 611, 612.
rubiacin, 606, 610, 611, 613–615.
rubian, 612.
saddening, 646.
safflower, 624–626.
saffron, bastard, 624.
sages, arsenic, 642.
salts, copper, 645, 646.
" iron, 646, 647.
" lead, 648.
sandal or santal wood, 626.
Santa Martha wood, 573.
santalin, 626.
sapan-wood, 573.
saunders-wood, 626.
Saussure's experiments on porous bodies, 764.
seed-lac, 600.
shell-lac, 600.
silk, preparing and dyeing of, 662–665.
soda, arseno-stannate of, 655, 656.
" stannate of. 654, 655.
sooranjee, 627–629.
spirit, barwood, 653.
" madder, 617, 618.
" plumb, 654.
spirits, red, 653.
" yellow, 653.
stannate of soda, 654, 655.
stanniferous mordants, 777–779.
statistics, 779–781.
stick-lac, 600.
straw color, light, 644.
sulphindigotic acid, 593.
sulphindylic acid, 593.
sulphopurpuric acid, 594.
sumach, 629–632.
" Venetian, 579
tannic acid, 581, 629–632.
tannin, 580, 581.
tartar, 649, 650.
terra Japonica, 574.
tin, 650–656.
" crystals of, 651.
" mordants, 777–779.
" protochloride of, 650, 651.
" salt of, introduced, 566.
" single and double muriate of, 650, 653.
topical dyeing, ancient, 567, 568.
Turkey-red, 567, 668–679.
" French processes, 670–672.
" Glasgow process, 669, 670.
" process with nitric acid, 674
" rationale of, 675–679.
" Swiss process, 672, 673.
" violets, 674, 675.
turmeric, 632, 633.
Tyrian purple, 566.
tyrosin, 578.
valerianic acid, 598.
variolaria, 570.
vat, cotton, 641.
" dripping, 586.
" German, 639, 640.
" Indian, 639.
" pastel, 636–639.
" potassa, 639.
" woad, 639.
" vats, construction and management of, 636, 640–642.
Venetian sumach, 579.
vermillion, 599.
violets, on Turkey-red system, 674, 675.
vitriol, white. 656.

DYEING & CALICO-PRINTING, *continued.*
volonia nuts, 632.
water, for madder-dyeing, 721, 722.
weld, or wold, 633.
Welter's bitter principle, 596.
white morin, 580.
xanthin, 612–615.
xanthorhamnin, 579.
yellow morin, 580.
" spirits, 653.
" wood, 580.
young fustic, 579, 629.
zinc, 656.

ELECTRO-METALLURGY, 782–816.
amalgamation of zinc, 787, 788.
anode, 792.
applications, 808.
argento-cyanide of potassium, 801.
auro-cyanide of potassium, 804.
batteries, voltaic, 784–790.
battery, Babington's, 785.
" Bunsen's, 787.
" Callan's or Maynooth, 789.
" Cruickshanks', 785.
" Daniell's constant, 786, 788, 789.
" magneto-electric, 790–792.
" now used, 785, 786.
" Smee's, 789, 790.
" Wollaston's, 785.
blacklead, 796.
Bradbury on Nature-printing, 811.
bright deposit, 802.
cathode, 792.
conducting power of metals, 787.
copper, deposition of, 805.
" patent for extracting from its ores, 808.
coppering cloth, 808.
copper-plates prepared by electro-deposit, 809, 810.
couronne de tasses, 784, 785.
daguerreotypes, copying of, 814.
Daniell's battery, cells for, by electro-deposition, 809.
definitions of terms, 792.
deposit, laws of, 807.
deposited moulds, 794.
deposition of alloys, 807.
" antimony, 806.
" bismuth, 807.
" brass, 807.
" cadmium, 806.
" copper, 805, 806.
" gold, 804, 805.
" iron, 806.
" lead, 806.
" nickel, 806.
" palladium, 805.
" platinum, 805.
" silver, 800–804.
" tin, 806.
" zinc, 806.
dies, copper, 809.
discovery of, 792, 793.
elastic moulds, 795, 796.
electricity, quantity and intensity of, 784.
electro-coppering, 805.
" gilding, 804.
" palladiating, 805.
" platinizing, 805.
" silvering, 800–804.
" zincing, 806.
electrode, 792.
electrolysis and electrolyte, 792.
electrotype, its original meaning, 809.
" process of, 793, 794.
Elkington, Messrs., electrotype factory of, 815.
fusible-metal moulds, 794, 795.
galvanism, 782–784.
gilding vat, 804, 805.
glass, patent process for silvering, 797.
glyphography, 810, 811.
gold solution, 804.
graphite, 796.
gutta-percha moulds, 795.
intensity of electricity, 784.
Kyhl's method of Nature-printing, 812.
laws of deposit, 807.
magneto-electric machine, 790-792.
Maynooth battery, 789.
metals, conducting power of, 787.
" positive and negative relations of, 786, 787.
motion, modes of communicating, 803.
moulds, 794–796.
Murray's application of plumbago, 795
Napier's patent for coppering cloth, 808.
Nature-printing, 811–814.
non-metallic moulds, 795, 796.
Palmer's glyphographic process, 810, 811.

with a similar bulk of ether. It possesses, according to the same authority, the following properties:—It is of a deep purple-red color, permanent in the air, and soluble in water, to which it communicates a very intense purple hue; alcohol also dissolves it, but with difficulty. It is insoluble in ether, and in fat and volatile oils. Its composition may be represented as $C_{32}\ H_{26}\ O_{20}$ N. Chlorine, iodine, and bromine destroy its color: the dilute acids impart to it a yellow tint, which reverts to purple on neutralizing the solution with an alkali. When dissolved in water, acids do not throw it down, but bitartrate and binoxalate of potassa render it scarlet. The alkalies cause it to become violet, and when its alkaline solution is exposed to the atmosphere, oxygen is gradually absorbed, and the coloring matter is decomposed. Hydrate of alumina causes the rapid formation of a pink lake, which, on being subjected to ebullition, acquires a violet tinge. Alum communicates a purple hue, but occasions no precipitate; acetate of lead gives a violet, chloride of tin a dark red, the salts of iron a brown, and those of copper a violet subsidence. The subsalts of mercury throw down a violet, and the protonitrate causes a scarlet precipitate. A solution of carméin is little affected by nitrate of silver.

The carméin or coccinellin of PELLETIER and CAVENTOU was rendered impure, according to DE LA RUE, by phosphoric acid, and by the presence of nitrogenous matter. The pure coloring principle of cochineal is termed, by the latter authority, *carminic acid;* from the properties—which he found it to possess—of uniting with bases, and being capable of abstracting some of them from their combinations with acetic acid.

Carminic acid may be prepared by precipitating an aqueous decoction of cochineal by oxide of lead, washing the subsidiary compound, and decomposing it by sulphide of hydrogen. The same procedure is repeated with the red filtrate so obtained. The colored menstruum procured from this second operation, is now evaporated to dryness *in vacuo* over sulphuric acid; the residue dissolved in absolute alcohol in a state of ebullition; the spiritous solution is digested with a portion of dry *carminate of lead* to remove all traces of phosphoric acid, and then concentrated; next it is diluted with an equal bulk of ether, which throws down the nitrogenous impurity in red flocculi, which contain some of the coloring matter: the liquid is finally filtered, and when it is evaporated, pure carminic acid remains.

When thus prepared, it is in the form of a purple-brown friable mass, transparent when viewed through a microscope; easily pulverizing to a fine red powder; soluble to any extent in water and spirit, but only slightly so in ether, which, however, does not throw it down from its alcoholic solution when it is free from nitrogenous matter. Hydrochloric and sulphuric acids, although in a concentrated state, dissolve without destroying it; nitric acid, even when very dilute, as also chlorine, iodine, and bromine, decompose it; the fixed alkalies and ammonia merely change the color of its aqueous solution to purple, but in the alcoholic tincture they produce purple precipitates; each of the alkaline earths causes a subsidence of a similar hue; sulphate of alumina gives no deposit, but on adding a drop of ammonia, the carminic acid is taken down as a beautiful crimson lake; acetates of lead, copper, zinc, and silver occasion purple precipitates, the latter of which is immediately decomposed, and metal separated; the nitrates of lead, mercury, and silver, furnish reddish deposits; proto- and bi-chloride of tin merely change the color to a deep crimson.

Carminic acid is composed of—

		Centesimally represented	
		Theory.	De la Rue.
28 Eqs. Carbon,	168	54·19	54·13
14 Eqs. Hydrogen,	14	4·52	4·62
16 Eqs. Oxygen,	128	41·29	41·25
1 Eq. Carminic acid,	310	100·00	100·00

It may be heated to 276° Fahr. without decomposition; on gradually increasing the temperature, a quantity of an acid liquor is produced, and at a red heat it intumesces and gives off a small quantity of ruddy fumes, which condense: there is no oily matter.

On boiling carminic acid with nitric acid, having a specific gravity of 1·4, oxalic and a new acid, termed by DE LA RUE nitrococcusic acid, are produced. The former is removed by the nitrate of lead, when the latter may be crystallized from the filtrate in rhombic plates of a yellow color, containing two equivalents of water of crystallization. It is bibasic, and all its salts are more soluble in water than the acid itself. It deflagrates when heated, as do also its salts, that of silver being very explosive. It is soluble in ether, alcohol, and water, and stains the cuticle yellow.

A number of analyses made by DE LA RUE, as well of the acid itself, as of its compounds, confirmed the adoption of the formula $C_{16}\ H_5\ O_{16}\ N_3$:—

		Centesimally represented.	
	At. weight.	Theory.	Experiment.
16 Eqs. Carbon,	96	33·45	33·75
5 Eqs. Hydrogen,	5	1·74	1·91
18 Eqs. Oxygen,	144	50·18	49·37
3 Eqs. Nitrogen,	42	14·63	14·97
1 Eq. Hydrated nitrococcusic acid,	287	100·00	100·00

The equivalent of the anhydrous acid as it exists in combination with bases is 269, and its composition is —

	At. weight.	Centesimally
16 Eqs. Carbon,	96	35·69
3 Eqs. Hydrogen,	3	1·12
16 Eqs. Oxygen,	128	47·58
3 Eqs. Nitrogen,	42	15·61
1 Eq. Anhydrous nitrococcusic acid,	269	100·00

The *crystallized* acid, obtained by evaporating its aqueous solution, is represented by the formula HO, $C_{16}\ H_3\ O_{16}\ N_3, + 2\ HO$.

The formula of such of the salts as have been analysed are annexed:—

Nitrococcusate of ammonia,	$2\ NH_4O,\ C_{16}H_3O_{16}N_3 + HO$.
" baryta,	$2\ BaO,\ C_{16}H_3O_{16}N_3 + 2\ HO$.
" potassa,	$2\ KO,\ C_{16}\ H_3\ O_{16}\ N_3$.
" silver,	$2\ AgO,\ C_{16}\ H_3\ O_{16}\ N_3$.

DE LA RUE says, further, with regard to nitrococcusic acid, that it may be represented by—

$$2\ HO,\ C_{16}\left\{\begin{matrix}H_3\\ N\,O_4\end{matrix}\right\}O_4,$$

and concludes that it is isomeric with the trinitroanisic acid of CAHOURS.

De la Rue obtained from the mother-liquor of carminic acid, a large quantity of a nitrogenous body, which could only be dried to a soft uncrystalline solid; he also procured from the same source a crystalline compound, closely resembling, both physically and chemically, that obtained by Liebig from casein, and by him termed *tyrosin.* One thousand parts of cochineal yielded about four of the new body. It is soluble both in alkalies and acids, and appears to be of the neutral class; it crystallizes in fine silky needles, slightly soluble in cold, but far more so in hot water; and insoluble in alcohol and ether. It has hitherto been represented by the formula $C_{18}H_{11}O_6N$.

The pigment known as *carmin* is generally prepared by subjecting cochineal to ebullition with carbonate of potassa or soda, and throwing down the coloring matter by a weak acid, or an acid salt; sometimes binoxalate of potassa, at other times a mixture of bitartrate of potassa with alum is employed; occasionally the precipitation is accelerated by the addition of gelatin or albumen.

A German process is to boil one pound of powdered cochineal in a gallon of water for a quarter of an hour, then adding one ounce of pulverised alum, and continuing the ebullition for three minutes longer; after this the vessel is removed from the fire, allowed to stand for some time undisturbed, and the clear supernatant liquid decanted into clean receptacles, which are set aside for several days, when about one and a half ounce of carmin is deposited. An additional half ounce of rather inferior quality is obtained by permitting the mother-liquor again to repose for a length of time.

The French make a decoction of cochineal by boiling one pound of it in three gallons of water for fifteen minutes; one ounce of powdered bitartrate of potassa is added, and after ten minutes' seething, half an ounce of alum. Ebullition is further continued for two minutes, and when, after the removal of the vessel from the fire, subsidence has occurred, the clear menstruum is set aside in clean glass pans, in which the carmin deposits. This is afterwards drained, and dried in the shade.

Madame Cenette's process, which has acquired some celebrity, is the following:—Mix two pounds of powdered cochineal, of the best quality, with fifteen gallons of boiling distilled water, and after two hours' ebullition, add three ounces of pure nitrate of potassa, and, in three minutes, four ounces of binoxalate of potassa. Boil for ten minutes longer, remove from the fire, allow to settle for four hours, carefully decant the clear liquor into shallow bell glasses, and set aside for three weeks. At the end of this time, the film of mould formed on the surface is dexterously removed, without disturbing the liquid portion, which is then drawn off by means of a pipette. The precipitated carmin left at the bottom of the vessels, when drained and dried in the shade, is of superior brilliancy and beauty.

Good carmin has not yet been manufactured in this country, although many attempts have been made to do so. The cause of failure, if one may judge from the following anecdote related by Sir H. Davy, is the absence of a certain actinic influence in the sun's rays in the more Northern climate of Britain:—

A maker of carmin, who was aware of the superiority of the French article, went to Lyons for the purpose of improving his process, and bargained with the most celebrated manufacturer in that city, for the acquisition of his secret, for which he was to pay £1000. He was shown all the various manipulation, and the most beautiful color produced, but he found not the least difference in the French mode of fabrication, and that which had been constantly adopted by himself: he appealed to his instructor, and insisted that he must have kept something concealed. The man assured him he had not, and invited him to inspect the process a second time: he minutely examined the water and the materials, which were, in every respect, similar to his own, and then, very much surprised, he found that his labor and money were lost, for the air of England acted prejudicially on the carmin. Stay, said the Frenchman, do not deceive yourself; what kind of weather is it now? A bright sunny day, replied the Englishman. And such are the days, said the Frenchman, in which good color is made. Were one to attempt to manufacture it on a dark and cloudy day, the results would be the same as yours. The French advice, then, is only to make carmin on bright sunny days.

Carmin is often adulterated with starch, alumina, or vermillion; oftentimes, also, a portion of the animal matter of the cochineal is accidentally mixed with it. These impurities are readily detected by heating the carmin with ammonia, which dissolves the coloring matter, and leaves the sophisticating body in an insoluble state.

It is perfectly impossible to judge positively of the quality of cochineal by its physical characters. In order to ascertain its value, recourse must be had to comparative experiments. Robiquet and Anthou have given two methods of determining the quality of cochineal, according to the quantity of carmin it contains. The process of the former consists in decolorizing equal volumes of decoctions of different samples of cochineal by chlorine, the same weight of each kind being taken. By using a graduated tube, the quality is judged of by the amount of chlorine employed for bleaching the menstruum. The method of M. Anthou is founded on the property which the hydrate of alumina possesses of precipitating the carmin from the solution, so as to decolorize it entirely.

The first process, which may be very good in the hands of a skilful chemist, does not appear to be a trustworthy method for the consumer; it being, in the first place, difficult to procure perfectly identical solutions; and in the next place, it is impossible to keep them a long time without alteration, as chlorine, when dissolved in water, reacts, even in diffused light, on this liquid, decomposes it, appropriates its elements, and gives rise to compounds which possess an action quite different from that of the chlorine solution in its primitive state.

The second mode of operation seems to be preferable, as the proof liquor may be kept a long while without change. A graduated tube is also used, each division representing one-hundredth of the coloring principle. Thus, the quantity of liquor added exactly represents the amount in hundredths of tinctorial matter contained in the decoction which has been submitted to examination.

Dr. **PENNY** has suggested a very simple process for ascertaining the comparative tinctorial powers of different specimens of cochineal. The method is based upon the bleaching action of ferricyanide of potassium in presence of a free alkali. Twenty grains of the cochineal finely pulverised are dissolved with a gentle heat, in two ounces of weak *aqua potassæ;* the menstruum is afterwards diluted with four ounces of water, and allowed to cool. A burette is then made up in the usual way, with water and five grains of the above-named test salt; and the solution added slowly to the cochineal liquid, until the purple color of the latter is discharged, and changed to a dull reddish-brown tinge. The precise moment when this result is produced, may be easily ascertained by spotting the liquid occasionally on a white slab. A comparative trial with cochineal of first quality will show at once the relative economic value of the sample under examination. This method also serves for testing lac dye.

Scarlet is communicated to wool and silk by dyeing first in a solution of annotta, and after by means of a mixture of a decoction of cochineal with cream of tartar and dyers' spirit, which is a mixture of protochloride and bichloride of tin; crimson is given by a decoction of cochineal with alum and chloride of tin without annotta.

FRENCH BERRIES.—*Grains d'Avignon*, French; *Gelbbeeren*, German.—The berries of the different species of *Rhamnus;* known also as Spanish and Turkey, but more especially as Persian, berries. They have been chemically examined by **CHEVREUL**, **HENRY**, **KANE**, and **PREISSER**. They are of two qualities: one of these comprises olive-green and larger berries than those of the other variety, which are brown and wrinkled, and appear to have remained longer on the trees. The coloring matter of the two kinds is, according to **KANE**, quite distinct.

In this, as in other cases, **PREISSER** asserts that the tinctorial principle may be brought to a colorless state by reducing agents; and when in this form he has termed it *rhamnin.*

It may be procured from an ethereal tincture of the berries, which, after being reduced by distillation to about one-third its original bulk, is mixed with water and a small quantity of hydrated oxide of lead; it is then filtered, and the entire coloring matter abstracted from the clear yellow liquor, by a further addition of the metallic oxide; this lead compound is next decomposed by sulphide of hydrogen, the clear filtrate evaporated to dryness, and the residue washed with ether.

Rhamnin is an almost colorless crystalline powder, of a bitter taste, and soluble in water, alcohol, and ether. Its solutions on exposure rapidly acquire a yellow hue, the rhamnin passing into *rhamnèin.* Nitric and chromic acids, bichromate of potassa, and other oxidizing agents, immediately produce the same change, and under the influence of alkalies the liquors acquire a dark-brown color.

Rhamnèin—*chrysorhamnin*—was obtained from the green berries by means of ether; it has a golden yellow color, and is crystallizable; it is almost insoluble in cold water, but dissolves in alcohol and ether. After desiccation at 212°, its formula, according to **KANE**, is $C_{23}\,H_{11}\,O_{11}$. When its alcoholic solution is decomposed by acetate of lead, a fine yellow precipitate falls, the composition of which, after having been dried at 212°, is represented by $2\,PbO,\ C_{23}\,H_{11}\,O_{11}$.

When rhamnèin is boiled in water, and in contact with air, it passes into *xanthorhamnin*—$C_{23}\,H_{12}\,O_{14}$.

1 Eq.	Rhamnèin, chrysorhamnin, ..	$C_{23}\,H_{11}\,O_{11}$
1 Eq.	Water, ...	$H\ O$
2 Eqs.	Oxygen, ...	O_2
1 Eq.	Xanthorhamnin, ...	$C_{23}\,H_{12}\,O_{14}$

Xanthorhamnin is contained in the brown shrivelled Persian berries, from which it may be procured by digesting them in hot water; it is insoluble in ether, but dissolves freely in water and in alcohol, and remains, on evaporating the infusion or tincture, in the form of an extract. **KANE** found its compound with oxide of lead to be $2\,PbO,\ C_{23}\,H_{12}\,O_{14} + 3\,HO$.

FUSTET—*Fustet*, French—is the name given to the wood of the *Rhus cotinus*, a shrub cultivated in Italy and Southern France, for the double purpose of a dyeing and tanning material. After being cut down it is deprived of its bark, and broken into small pieces, in which state it is met with in commerce. It is also termed *young fustic—bois de fustet*—in contradistinction to the wood of *morus tinctoria*, which is also denominated fustic—and has been known as *Venetian sumac.* It has long been used in France for giving a yellow dye. In the south of that empire the leaves of *Rhus myrtifolia* are also employed for tinctorial purposes, under the appellation of *redoul*, or *rodou.* Fustet affords a yellow crystalline coloring matter, which **PREISSER** has separated thus:—The tannic acid was first precipitated from the decoction by means of gelatin; on filtering, a greenish-yellow liquor was obtained, which was evaporated to dryness, and the residue treated with ether. This solution was distilled in a retort, and water, together with hydrated oxide of lead, added to the residue, causing the formation of a yellow compound, which was decomposed by sulphide of hydrogen; the liquor yielded small yellow crystals of *fustin*, which were purified by edulcoration with ether.

Fustin is slightly bitter; it dissolves in water, alcohol, and in ether, and acquires color on exposure to the atmosphere. Sulphuric and nitric acids communicate a yellow tinge to its solutions. Tin salts cause an orange-yellow, and those of iron an olive-green precipitate. Acetate of lead causes a subsidence at first white, but on exposure becoming yellow. The alkalies immediately redden the solution Fustin appears to resemble rhamnin, and has a great tendency to absorb oxygen from the air; this latter property affects its use as a dye. The colors being fugitive, it is seldom employed alone, but as an assistant to strike some particular tint. It is not used in the dyeing of cotton goods.

FUSTIC.—*Bois-jaune*, French; *Gelbholz*, German

—The wood of the *morus tinctoria.* This dye-stuff has been long known. It is uncertain when it was introduced, but mention is made of it in a book published in 1692. The tree grows spontaneously in Brazil and the West Indian islands, and attains a great altitude. The wood is of a sulphur color, with veins of an orange hue.

Fustic, or, as it has been termed, *yellow wood,* has been severally examined by Georges, Chevreul, and Preisser. The results of the first of these have long been regarded as unsatisfactory. Chevreul says that two coloring principles exist in the yellow wood capable of dyeing alumed stuffs yellow, and has called them *yellow* and *white morin.* Both sublime in crystals. They are distinguished by the aqueous solution of the yellow morin becoming green with sesquisulphate of iron, whilst that of the white turns chestnut red.

The white morin is found principally in the crystalline powder which exists in the heart of the tree. The yellow morin, or, as Preisser termed it, *morëin,* is procured by exhausting the wood with water, evaporating the extract until it deposits crystals on cooling, dissolving these in ether, and allowing them to re-form. These two principles are easily altered by the air, by exposure to which they acquire a reddish tint.

The experiments of the last-named chemist led to the conclusion that the white and yellow morin were only modifications of one and the same body, and on adopting the same process of extraction as for other coloring matters, he obtained *morin*—or white morin—which, in contact with the atmosphere, absorbs oxygen, assumes a yellow color, and is converted into morëin.

Morin is dissolved by mineral acids, which communicate to it a yellow color. Sesquisulphate of iron tinges it garnet-red. Acetate of lead gives a white precipitate. Alkalies cause it to take a beautiful dark yellow, approaching to orange. It absorbs oxygen on being boiled in water, and is changed into morëin, which deposits on cooling. The same result is attained more speedily by oxidising morin by chromic acid or bichromate of potassa. Both furnish morëin and oxide of chromium.

Morëin crystallizes in beautiful yellow laminæ. It is volatile; perceptibly acid to litmus paper; not very soluble in cold, but more so in boiling water; it is readily taken up by alcohol or ether; acids dissolve it and darken the color; nitric acid tinges it brownish-red, and causes the evolution of ruddy fumes; alkalies change its hue to orange; acetate of lead causes a golden-yellow, and sesquisulphate of iron a dark-green precipitate.

Morëin is not very permanent. After a time it appropriates a further quantity of oxygen, and becomes reddish-brown. This absorption is perceptible when the solution is brought into contact with oxygen over mercury. This is the cause of the red and brown principles which always occur in decoctions of fustic, and which exist at the surface of the wood, when it has been exposed to the action of air and light for any length of time.—*Preisser.*

Fustic has long been partially superseded for the dyeing of yellows upon cotton by quercitron bark, and both are now almost totally displaced by bichromate of potassa and lead. Fustic is, however, sometimes used in giving a green color to cotton yarn. The goods are first dyed blue, and are then passed through crude acetate of alumina; they are next subjected to the action of a hot decoction of fustic, which communicates a rich shade of green. The same color is also often imparted to light cotton tissues, as gauzes and muslins, by similar means. It is still much used for greens on silk and woollen; it is also employed with other woods for compound hues, as drabs, fawns, olives, *et cetera,* and is used with logwood for dyeing black, as well on cotton, as on silk and woollen fabrics.

Galls—*Noix de Galle,* French; *Galläpfel,* German; *Gallæ,* Latin—are excrescences which form upon the branches and shoots of *Quercus infectoria,* being caused by the puncture of the female of the *Cynips gallæ tinctoria,* or gall-wasp, which deposits its egg in the perforation, occasioning the development of the nut, within which the larva is perfected, and whence it finally eats its way out. Those of the best quality are known in commerce as black or blue galls, and are collected before the insect has escaped; the white galls are those from which it has departed, and are, consequently, perforated with a small circular hole. They are of a brownish or dingy-yellow color, and are larger than the others, but are not so heavy or astringent. Gall-nuts are chiefly imported from Turkey; they were used in medicine in the time of Hippocrates, and have also been very long known as sources of black dye, and employed in the manufacture of writing inks. The first attempt at an analysis of them was made about the middle of last century by Dr. Lewis, who detected in them a substance which, said he, *coagulates with isinglass and blackens solutions of iron.* Deyeux regarded their active principle as a resin. Seguin was probably the first who accurately determined the nature of its action upon solutions of gelatin, and upon the skins of animals, and who applied the generic term *tannin* to this principle, as existing in a variety of substances employed in the conversion of hides into leather.

From an aqueous decoction of five hundred parts of galls, Sir Humphrey Davy obtained one hundred and eighty-five parts of solid extract, which he found to consist of—

Tannin,	130
Gallic acid,	31
Mucilage,	12
Inorganic matter,	12
	185

From the analyses of Guibourt, the following constituents were found to pre-exist in them:—

	Centesimally represented.
Tannic acid,	65·0
Gallic acid,	2·0
Ellagic and luteo-gallic acids,	2·0
Brown extractive substance,	2·5
Gum,	2·5
Starch,	2·0
Sugar,	1·3
Clorophyl and volatile oil,	0·7
Woody fibre,	10·5
Water,	11·5
Albumen and salts,	—
	100·0

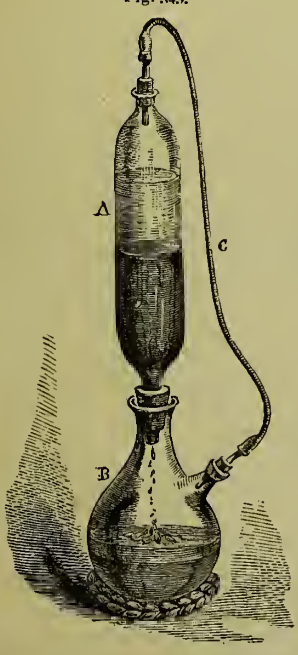
An infusion of galls occasions precipitates in most metallic solutions, the characters and colors of which are sometimes accepted as indications of the oxide present In the following table, abridged from BRANDE, the solution of the metallic salt employed is shown in the first column, and the third and fourth give the color of the precipitate; the first of the two latter columns being the results obtained by BRANDE, the latter those of DUMAS. It may be observed, says the former authority, that discrepancies arise in this case from the strength of the metallic solution, and also from its acid or basic character, so that neutral menstrua should as far as possible be used.

Solution of metallic salt.	Color of precipitate.	
	Brande.	Dumas.
Protochloride of manganese,....	Dirty-yellow.	—
Protosulphate of iron,........	Purple tint.	—
Sesquisulphate of iron,........	Black.	Blue-black.
Chloride of zinc,..............	Dirty-yellow.	—
Acid protochloride of tin,......	Straw color.	Yellowish.
Acid bichloride of tin,.........	Fawn color.	Fawn color.
Protochloride of copper,.......	Yellow-brown.	?
Nitrate of copper,............	Green.	Grey.
Nitrate of lead,...............	Dingy-yellow.	White.
Tartrate of antimony and potassa,	Straw color.	White.
Chloride of cobalt,............	—	Yellow-white.

Tannin or tannic acid, the chief constituent of galls, was not obtained in a pure state until 1834, when a method of separating it was pointed out by PELOUZE, which enabled him to examine its properties, and ascertain its composition.

The process is as follows:—A glass vessel similar to that represented by A—Fig. 349—is fitted into a two-necked flask, B; the upper recipient is about half filled with powdered galls, a small plug of cotton wool being placed at its lower conical end to prevent any of the powder passing through; washed ether—that is, ether containing about a tenth part of water—is then poured upon the galls, till, when they have absorbed as much as possible, the vessel is nearly full. The perforated corks, with the elastic tubing, C, are then replaced, and percolation allowed to proceed. The liquid, as it flows into B, divides into two strata, the lower of which is a concentrated aqueous solution of tannic acid, the upper being ether containing a little tannic and gallic acid. These menstrua are separated, and the lower, having been agitated or washed with *pure* ether, is evaporated, *in vacuo*, over sulphuric acid; aqueous and ethereous vapors pass off, and the pure tannin is obtained as a bulky pale-yellow residue. According to PELOUZE, the tannin of galls is more soluble in water than the other constituents, so that it abstracts the water from the ether, and forms with it the lower stratum of liquid, upon which the ether itself floats. When the powder of gall-nuts is treated with pure anhydrous ether, a magma is formed, and no fluid separates, but, according to GUIBOURT, a little alcohol in the ether facilitates the process. The method above described, however, answers well, and although other processes have been suggested by BERZELIUS, CADET, and others, that of PELOUZE appears, upon the whole, to be the simplest and most effectual.

Fig. 349.



Pure tannic acid is nearly colorless, inodorous, pre-eminently astringent in taste, uncrystallizable, very soluble in water, and less so in pure alcohol and ether. Its aqueous solution reddens litmus, and decomposes the alkaline carbonates with effervescence. It combines energetically with gelatin, and when a piece of skin or bladder is immersed in its aqueous solution, the tannic acid is entirely abstracted; whereas, any gallic acid that may be present, remains dissolved. It also furnishes an abundant white precipitate in menstrua containing isinglass or glue. A concentrated aqueous solution of tannic acid is thrown down by hydrochloric, nitric, sulphuric, phosphoric, and arsenic acids; but not by oxalic, tartaric, lactic, acetic, or citric acid. By the prolonged action of acids and alkalies, it undergoes various and often complicated changes, amongst which, its conversion into gallic acid is most common.

Tannic acid has been analysed with the following results:—

	At weight.	Centesimally represented.			
		Theory.	Berzelius.	Liebig.	Pelouze.
18 Eqs. Carbon,....	108	50·94	52·69	52·51	51·77
8 Eqs. Hydrogen,..	8	3·77	3·86	4·12	3·98
12 Eqs. Oxygen,.....	96	45·29	43·45	43·37	44·25
1 Eq. Tannic acid,	212	100·00	100·00	100·00	100·00

According to BERZELIUS and PELOUZE, tannic acid is anhydrous, and tannate of lead, when dried at 120°, is represented by them as $Pb\,O,\ C_{18}\,H_8\,O_{12}$. LIEBIG, by adding tannic acid to an excess of a hot solution of acetate of lead, obtained a salt which he considers to be $3\,Pb\,O, C_{18}H_5O_9$; he consequently regards the tannic acid as *tribasic*, and represents it, when isolated, by the formula $3\,H\,O,\ C_{18}H_5O_9$. LÖWIG regards it as monohydrated, and gives to it the formula $H\,O,\ C_{18}\,H_7\,O_{11}$, which, he observes, is consistent with all its salts except LIEBIG'S tannate of lead.

An aqueous solution of tannic acid out of contact with air, sustains no alteration; but, if exposed to the atmosphere, it gradually loses its limpidity, and a slightly greyish crystalline matter, consisting almost entirely of gallic acid, subsides. This change is facilitated by diluting the menstruum. For procuring gallic acid in a perfectly pure state, it is merely necessary to treat the above solution, after its mutation, with animal charcoal, and to filter it in a state of ebullition, through paper previously washed with dilute hydrochloric acid. The acid falls down in crystals as the liquid cools. If a solution of tannic acid be exposed to the action of oxygen in a glass jar over mercury, the gas will be absorbed, a corresponding volume of carbonic acid will be evolved, and in the course of a few weeks the liquor will appear as if traversed with numerous crystalline colorless needles of gallic acid.

Gallic acid may also be obtained by mixing powdered galls with water, and exposing the paste for some weeks to the air, at a temperature of 70° to 75°, occasionally adding water to prevent desiccation; the powder swells and becomes mouldy, and when the magma is subjected to pressure, a quantity of colored liquid may be squeezed out; the residue is then boiled in water, and the solution filtered while hot; on cooling, it deposits crystals of gallic acid, which may be purified by redissolving, and boiling with a little animal charcoal; the filtered solution then deposits the gallic acid in the form of white silky needles. Or, by another method, a concentrated cold infusion of gall-nuts is precipitated by sulphuric acid; the subsidence is first washed with very dilute sulphuric acid, pressed out, and then dissolved in the same menstruum—consisting of one part of acid to two of water—and boiled for some minutes; on cooling, it deposits crystals which are to be purified by a second crystallization, dissolved in hot water, and thrown down by acetate of lead; the resulting gallate of lead is then well washed, diffused in boiling water, and decomposed by a current of sulphide of hydrogen; colorless crystals of gallic acid are deposited as the filtered liquor cools.

E. N. Kent, in 1844, published a mode of preparing gallic acid from black ink. For this purpose, a portion of ink is well agitated with an equal quantity of pure sulphuric ether; the mixture is left at rest for a few minutes, and the ether having then separated, is decanted, and distilled nearly to dryness; the residue crystallizes on cooling. The ether may be returned to the ink, and the process repeated. The gallic acid may be purified by repeated crystallizations, or by precipitating its solution with acetate of lead, decomposing the resulting compound by sulphide of hydrogen, and crystallizing.

The remainder of the ether may be distilled off from the ink, which is left as good for *ordinary* purposes as before.

Most of the inks tried by the author of this method, gave the same result when treated with ether. Some, however, which had been prepared by boiling the galls, and exposure for a few days only, yielded principally tannic acid, and it is therefore advisable to test the ink with gelatin before attempting to thus prepare gallic acid.

Gallic acid crystallizes in long silky needles, of a slightly sour and astringent taste, soluble in about one hundred parts of cold, and in three of boiling water; it is readily soluble in alcohol, and sparingly so in ether: it occasions no precipitate with gelatin. The composition of the crystals is variously represented; the formula is probably $H O, C_7 H_3 O_5$. The acid dried at 212° Fahr. consists of—

		Centesimally represented.			
	At. weight.	Theory.	Pelouze.	Liebig.	Stenhouse.
7 Eqs. Carbon,	42	49·41	50·10	49·85	49·49
3 Eqs. Hydrogen,	3	3·53	3·64	3·48	3·53
5 Eqs. Oxygen,	40	47·06	46·26	46·67	46·98
1 Eq. Gallic acid, dried at 212°	85	100·00	100·00	100·00	100·00

But it is probable that the acid dried at 212° still retains an atom of water, being $2 H O, C_7 H O_3$.

Basic salts of gallic acid, when exposed to the atmosphere, absorb oxygen, acquiring various shades of yellow and brown, till they ultimately blacken, in consequence of the formation of melanotannic acid—$2 H O, C_{14} H_4 O_7$.

According to Robiquet, gall-nuts contain, besides tannin and the several principles which have already been pointed out by chemists, pectose and pectase. The latter, which exists both in the soluble and the insoluble state, acts synchronously upon the pectose and upon the tannic acid, converting the first into pectin, and the second into gallic acid. The presence of water and a temperature of 77° to 86° are requisite for this reaction, which resembles in every respect the ordinary phenomena of fermentation.

Ordinary tannic acid, which has been prepared with ether, contains sufficient pectase to pass spontaneously in the presence of water into gallic acid; but if care has been taken to purify it, or if its solution has been simply boiled for a few minutes, the change no longer occurs.

Synaptase, yeast, vegetal albumen, and legumin, have a very doubtful action upon tannin, and retard rather than accelerate its conversion into gallic acid.

In addition to gallic acid, formed on the exposure of moistened galls to the atmosphere, another principle, which seems to have been first observed by Chevreul, and denominated by Braconnot *ellagic acid*—a term derived from the word *galle* read backwards—is produced. It is insoluble in boiling water, and therefore remains after the gallic acid has been extracted. It may be dissolved out of the residue by very weak *aqua potassæ*, from which it is precipitated by hydrochloric acid as a tawny powder, tasteless, and almost insoluble in water, alcohol, and ether. According to Pelouze, ellagic acid dried in the air may be represented by the formula $H O, C_7 H_2 O_4$. It is rendered anhydrous by drying at 250°, and then consists of—

		Centesimally.	
	At. weight.	Theory.	Pelouze.
7 Eqs. Carbon,	42	55·3	55·69
2 Eqs. Hydrogen,	2	2·6	2·48
4 Eqs. Oxygen,	32	42·1	41·83
1 Eq. Anhydrous ellagic acid,	76	100·0	100·00

It faintly reddens litmus. Wöhler, in remarking upon its existence in the intestinal concretions known as *oriental bezoars*, gives its formula as $H O, C_{14} H_2 O_7$, and says there is no doubt of the latter being more correct.

Pyrogallic acid was first obtained by Scheele, by subliming galls; he considered it to be identical with gallic acid. It has subsequently been investigated by Deyeux, by Braconnot, by Pelouze, and, more recently, by Dr. Stenhouse. It may be procured by drying gallic acid at 212°, and then heating it in a small glass retort, immersed in an oil-bath, to a temperature of 410° to 420°. Sublimation occurs, and it is deposited in white brilliant lamellar crystals. When thus obtained, it is very liable to be contaminated with empyreumatic oil, and can only be purified by repeated distillations, in each of which much acid is unavoidably lost, and the process thus rendered extremely troublesome and unproductive. The process recommended by STENHOUSE is as follows:—

Finely pounded gall-nuts are treated with successive portions of cold water, till they are exhausted. These extracts are then evaporated and strongly dried, till all the hygrometric water is driven off, and in this state they form a spongy deliquescent mass, in state and color very much resembling catechu. Instead of distilling this in a retort, it is much better to employ Dr. MOHR'S apparatus for subliming benzoic acid. This consists of a cast-iron pan, from three to four inches deep, and from eighteen inches to two feet wide. The dried extract is coarsely powdered, and spread equally over its bottom to the depth of about half an inch; the top of the pan is then covered with a diaphragm of bibulous paper—if this be pierced with a few small pin holes, the sublimation will be greatly facilitated—fitted closely over it by being pasted round its rim. The pan is surmounted with a paper cap twelve or eighteen inches high, well adapted to its top, and fastened by means of a cord passed two or three times round it. The apparatus is to be cautiously heated for ten or twelve hours on a sand, or still better, on a metallic bath, keeping the temperature as nearly as possible at 400°, though towards the end of the process it may be raised a few degrees higher.

The crystals of pyrogallic acid pass through the bibulous paper, which absorbs the empyreumatic oil by which they are always accompanied. Should the heat have been carefully regulated, the crystals, which are either large scales or needles, are perfectly white; if they are at all colored, which frequently happens, they may be easily purified by a second sublimation. This method possesses the great advantage, that a pound or more of the extract can be operated on at once; the apparatus is extremely cheap, and as it is not liable to break, it may be used for any number of times. On one trial, one thousand three hundred and eighty grains of dried extract yielded sixty-nine grains of perfectly pure crystals, and seventy-four grains which were slightly colored, in all one hundred and forty-three grains, or 10·3 per cent. As galls yield rather more than half of their weight of soluble matter, the quantity of pyrogallic acid obtainable from them by this process is very considerable. Dr. STENHOUSE mentions, however, that on a previous trial, when the sublimation was not so carefully conducted, he did not obtain more than half this quantity.

Pyrogallic acid is white, crystalline, and inodorous, but has a very bitter taste, resembling that of salicin. When pure, it does not change blue litmus paper; but if it has been sublimed at too high a temperature, it is accompanied with a little of some volatile acid, which causes it to redden litmus slightly. It gives a deep blue indigo color, but no precipitate, with solutions of protosulphate of iron; should sesquioxide be present, this hue soon changes to dark green, but if the salt is pure, the deep-blue remains for a considerable time. With sesquisulphate of iron it gives a yellowish, and with sesquichloride a much brighter red, but in neither case is there any deposit. When dropped into milk of lime, a reddish-purple color appears, speedily changing to brown. Caustic baryta occasions a dark-brown hue, readily becoming black. Dilute sulphuric acid first reddens, and then blackens it. Iodine leaves it intact. Chlorine immediately changes the color of the crystals to red, which, however, soon turns black.

Pyrogallic acid reduces the oxides of gold, silver, and platinum to the metallic state, completely precipitating them from their solutions.

BERZELIUS represented pyrogallic acid by the formula $C_6 H_3 O_3$, the equivalent of which is 63. STENHOUSE gives the composition as $C_8 H_4 O_4$. This statement is confirmatory of that made by CAMPBELL. The composition is as under:—

		Centesimally.	
	Atomic weight.	Theory.	Stenhouse.
8 Eqs. Carbon,..............	48	57·14	57·60
4 Eqs. Hydrogen,...........	4	4·76	4·78
4 Eqs. Oxygen,..............	32	38·10	37·62
1 Eq. Pyrogallic acid,......	84	100·00	100·00

Of pyrogallic acid, so little is still known that it is even doubtful if it possesses acid properties, since a single drop of ammonia added to its solution rendered it alkaline, and caused it to assume a dark-brown color. According to STENHOUSE, it does not combine with alkalies. On adding to it an excess of ammonia, and evaporating *in vacuo*, the acid crystallized in dark-brown confused tufts, entirely free from the alkaline base.

By heating gallic acid to different degrees, and under various circumstances, many bodies are formed; as by heating gallic with sulphuric acid to 285°, and mixing the solution with water, the deposit of a red crystalline substance is caused, which has been termed *paraellagic acid*, its ultimate components being the same as those of ellagic acid before noticed. *Metagallic* or *melanogallic acid*, is formed when dry gallic acid is heated rapidly to 480°; carbonic acid and water are evolved; and, instead of pyrogallic acid being sublimed, a black, shining, and tasteless body is produced, insoluble in water, alcohol, and ether; dissolving in the alkalies; precipitated thence by acids in the form of a black powder; capable of expelling carbonic acid from the alkaline carbonates; neutral to vegetal colors; producing black deposits in solutions of lime, magnesia, lead, copper, iron, and zinc; its formula evidently being $HO, C_{12} H_3 O_3$, and the resulting equivalent 108. In combination its atomic weight is 99, and its composition—

		Centesimally.	
	Atomic Weight.	Theory.	Pelouze.
12 Eqs. Carbon,.................	72 ..	72·72 ..	72·86
3 Eqs. Hydrogen,...............	3 ..	3·04 ..	3·18
3 Eqs. Oxygen, ...	24 ..	24·24 ..	23·96
1 Eq. Anhydrous metagallic acid,	99	100·00	100·00

Melanotannic acid is obtained by heating a solution of tannic or gallic acid with excess of potassa in contact with the atmosphere, till a precipitate of gallic acid is no longer given on supersaturating the menstruum with acetic acid, with which it is then evaporated to dryness, and the black residue washed with dilute alcohol to remove the acetate of potassa. The product is then dissolved in water, acidulated with acetic acid, and thrown down by acetate of lead; a brownish-black compound falls, which, when dried, becomes pulverulent, and has the composition $2\ \mathrm{Pb\,O},\ \mathrm{C}_{14}\ \mathrm{H}_4\ \mathrm{O}_7$. BÜCHNER consequently represents melanotannic acid as $2\ \mathrm{H\,O},\ \mathrm{C}_{14}\,\mathrm{H}_4\ \mathrm{O}_7$.—*Brande.*

When trying, for practical purposes, the difference of effect produced by the sesquisulphate and protosulphate of iron upon pure tannic and gallic acids, the changes produced with the former are somewhat similar to those which occur in a solution of galls. With gallic acid the sesquisulphate gives at first a black precipitate, not so dark as the tannate, but in a few minutes it changes to an olive, and continues to vary till it becomes almost colorless. With the protosulphate, at first the tinge is scarcely visible, but after an hour's exposure it assumes a rich violet. From these facts it may be concluded, that tannic is superior to gallic acid as a dyeing agent for black; moreover, the compound formed is less soluble.

Another circumstance which modifies the results of these experiments in their application to dyeing, is the quality of the water used. If the experiments be performed with distilled, it will be found on repeating them with common spring water, that one-half of the quantity of stuffs will give the same depth of color, and that, in this instance, there is more of a purple hue, and the colors are much more permanent. This may be illustrated by a very simple experiment. Take two glass jars of equal size, fill them half full with distilled water, and add an equal quantity of a solution of galls or sumac; put into each an equal number of drops of a solution of protosulphate of iron; the change is scarcely perceptible; but fill up one to the brim with spring water, and it almost instantly becomes a dark reddish-black. Allow both vessels to stand for an hour, the solution with the distilled water will have become a deep violet, while the other, notwithstanding the double quantity of water, is so dark that no light is transmitted; and it will require one-half more water to reduce it to the same shade as the other, but still retaining more of the reddish hue, which, however, makes it superior for black. It will also be found to be much more insoluble, and to require a greater proportion of acid to decompose it. If soft or filtered river water be used instead of distilled, the distinction is not so great; but still the difference is equal to one-half. The best water found for dyeing black and other colors darkened by sulphate of iron, which include drabs, fawns, slates, grey, some kinds of browns, blacks, *et cetera*, gave, by analysis, sulphuric, hydrochloric, and carbonic acids, lime, a trace of silica, and iron. The solid contents were in large quantity, but did not exceed one grain in a fluid ounce, or one hundred and sixty grains per gallon. These ingredients existed in the water as sulphate and carbonate of lime, chloride of calcium, and carbonate of iron; the latter was in very small proportion, the carbonic acid and lime greatest.

Now, a dyer learning his trade in an establishment where such water was used, could not fail to become successful with such colors as have just been recounted; but were he taken from it to another where soft filtered water was used, what would be the result? When he attempted to obtain a black with the same quantity of dye-stuff he formerly used, he would only produce a dark slate color; and if he wished to obtain slate, he would produce grey. In this dilemma, the dyer adds stuff till he comes to the desired shade; but fancy dyes bolstered up with stuffs are not so pretty; besides, the employer, in consequence of this addition, must either submit to a loss or discharge the workman, who, no doubt, would consider himself ill used, talk loudly of his ability in dyeing such colors, and offer to prove that the fault is not in him but in the water.

Dyeing being an art wholly dependent upon chemistry for its development and success, he who practises it without studying chemistry, is like a boy learning to repeat a number of choice sentences from an author without knowing his letters. Had the dyer, in such a case, known the principles of chemistry, so far as they are applicable to his trade, he would, on finding that the same quantity of stuffs did not yield similar results, have examined the water to discover where lay the difference, and in this instance he would find, that instead of employing an extra quantity of sumac, sulphate of iron, and logwood, to get a good black, the addition of a little chalk and hydrated sulphate of lime to the water, would so qualify it as to render it as effective as that to which he had been accustomed.—*Napier.*

INDIGO.—*Indigo*, French; *Indigo*, German.—This invaluable dye-stuff, for which no substitute has been found, was known to the ancients under the name *Indicum*, whence its modern appellation. In modern Europe, it first came into extensive use in Italy; but about the middle of the sixteenth century, the Dutch began to import and employ it in considerable quantity. Its general introduction into the dye-houses of both England and France was kept back by absurd laws,—see the historical notice at the commencement of this article,—founded upon an opinion that it was a fugitive substance, and even prejudicial to the fibre of wool.

Indigo is derived from a genus of leguminous plants found in India, Africa, and America, named *Indigofera.* Botanists have described about sixty species of this genus, all yielding indigo; but those from which it is usually obtained are the *I. anil*, the *I. argentea*, and the *I. tinctoria.* It is also extracted from a tree very common in Hindostan—*nerium tinctorium*—and from the woad plant—*isatis tinctoria*—which is a native of Great Britain, and of other parts of Europe. The coloring matter of these plants is wholly in the cellular tissue of the leaves, as a secretion or juice; not, however, in the blue state in which one is accustomed to see indigo, but as a colorless substance, which continues white so long as the tissue of the leaf remains perfect: when this is by any means destroyed, oxygen is absorbed from the atmosphere, and the principle becomes blue.

In the East Indies, after having ploughed the ground in October, November, and the beginning of December, the seed of the indigo plant is sown in the last half of

March or the beginning of April, while the soil, being neither too hot nor too dry, is most propitious to its germination. A light mould answers best; and sunshine, with occasional light showers, are most favorable to its growth; when much rain falls, however, the plants grow too rapidly, and do not sufficiently elaborate the blue. Twelve pounds of seeds are sufficient for sowing an acre of land. The plants grow rapidly, and will bear to be cut for the first time at the beginning of July; in some districts, even so early as the middle of June. The indications of maturity are the bursting forth of the flower-buds, and the expansion of the blossoms; at which period the plant abounds most in the dyeing principle: another token is taken from the leaves, the breaking across of which, when doubled flat, is accepted as a sign of ripeness; but this character is somewhat fallacious, and depends much upon the poverty or richness of the soil.

The first cropping of the plants is the best; after two months a second is made; after another interval a third, and even a fourth; but each of these is of diminished value. There are only two cuttings in America.

Two methods are pursued to extract the indigo from the plant: the first effects it by fermentation of the fresh leaves and stems; the second by maceration of the dried leaves—the latter process being deemed most advantageous.

In the indigo factories of Bengal, there are two large stone cisterns, the bottom of the first being nearly on a level with the top of the second, to allow the liquid contents to be run out of the one into the other. The uppermost is called the fermenting vat, or steeper; its area is twenty feet square, and its depth three feet; the lowermost, called the beater or beating vat, is as broad as the other, but one-third longer. The cuttings of the plant, as they come from the field, are stratified in the steeper, till it is filled within five or six inches of its brim. In order that the plant, during its fermentation, may not swell and rise out of the vat, beams of wood and twigs of bamboo are braced tight over the surface of the plants, after which water is pumped upon them till it stands within three or four inches of the edge of the vessel. An active fermentation speedily commences, which is completed within fourteen or fifteen hours, a little longer or shorter, according to the temperature of the air, the prevailing winds, the quality of the water, and the ripeness of the plants. Nine or ten hours after the immersion of the plant, the condition of the vat must be examined; frothy bubbles appear, which are at first white, but soon become grey-blue, and then deep purple-red. The fermentation is at this time violent, the fluid is in constant commotion, apparently boiling, innumerable bubbles mount to the surface, and a dense scum of a cupreous hue covers the whole. As long as the liquor is thus agitated, it must not be interfered with; but when it becomes more tranquil, it is to be drawn off into the lower cistern. Great care is required at this point of the operation, for should the fermentation be pushed too far, the quality of the whole indigo is deteriorated; it is even better to cut it short, in which there is indeed a loss of weight, but the article is better and the returns more profitable. The menstruum now possesses a glistening yellow color, which, when the indigo precipitates, changes to green. The average temperature of the liquid is commonly 85° Fahr.

As soon as the liquor has been run into the lower cistern, men are set to work to beat it with oars or paddles, about four feet long, called *busquets*. Paddle-wheels have also been employed for the same purpose. Meanwhile other laborers clear away the compressing beams and bamboos from the surface of the upper vat, remove the exhausted matter, set it to dry for fuel, clean out the vessel, and stratify fresh plants in it. The fermented plant still appears green, though it has lost three-fourths of its bulk in the process, or from twelve to fourteen per cent. of its weight, chiefly water and extractive matter.

The liquid in the lower vat must be strongly beaten for an hour and a half, when the indigo begins to agglomerate in flocks, and to precipitate. This is the moment for judging whether there has been any error committed in the fermentation, which must be corrected by the operation of beating. If the fermentation has been defective, much froth arises during the agitation, which must be allayed with a little oil, and then a reddish tinge appears. If large round granulations are formed, the beating is continued to make them smaller, if possible. Should they become as small as fine sand, the water at the same time clearing up, the indigo is allowed quietly to subside. In case the vat was over-fermented, a thick fat-looking crust covers the liquor, which does not disappear by the introduction of a flask of oil. In such a case the beating must be moderated. Whenever the granulations become round and begin to subside, and the liquor clears up, the beating must be discontinued. The froth or scum diffuses itself spontaneously into separate minute particles, which move about the surface of the liquor, and are marks of an excessive fermentation. On the other hand, a rightly fermented vat is easy to work; the froth, though abundant, vanishes as soon as granulations make their appearance. The color of the liquor, when drawn out of the steeper into the beater, is bright-green, but as soon as the agglomeration of the indigo commences, it assumes the color of Madeira wine; and speedily afterwards, during the beating, a small round grain is formed, the separation of which makes the water transparent, and causes the disappearance of all the turbidity and froth.

In order to hasten the precipitation, lime-water is occasionally added to the fermented menstruum in the progress of beating, but it is not indispensable, and has been supposed to deteriorate the indigo. Two or three hours after the agitation, the supernatant liquid is run off, and by its condition affords a good indication of the success of both the processes. A laborer then enters the vat, sweeps all the precipitate into one corner, and empties the more elutriated portion into a spout leading into a cistern, situated beside a boiler, twenty feet long, three wide, and three deep. When all the deposit is once collected, it is pumped through a bag, for retaining the impurities, into the boiler, and heated to ebullition. The froth soon subsides, and shows an oily-looking film upon the surface. The indigo is by this means not only freed from the yellow extractive matter, but enriched in the intensity of its color, and increased in weight. Some manufacturers, however, prefer retaining it at a moderate temperature throughout, and affirm that a deeper hue is produced. From the boiler the mixture is run, after two or three hours, into a general receiver, called the *dripping* vat, or table, which, for a factory with twelve pair of preparation vats, is twenty feet long, ten wide, and three deep, having a false bottom two feet below the top edge. This cistern stands in a basin of masonry, made watertight with hydraulic cement, the bottom of which slopes to one end, in order to facilitate the drainage. A thick woollen web is stretched along the bottom of the inner vessel to act as a filter. As long as the liquid passes through turbid, it is pumped back into the receiver; but as soon as it runs clear, the latter is covered with another piece of cloth to exclude the dust, and percolation is allowed to proceed spontaneously. Next morning the drained magma is put into a strong bag, and squeezed in a press. The indigo is then carefully taken out, and cut with a brass wire into pieces of about three cubic inches each, which are exsiccated either in a stove upon boards, or in an airy room upon shelves of wicker work. During the drying, a whitish efflorescence appears upon the pieces, which must be carefully removed with a brush. In some localities, particularly on the coast of Coromandel, the desiccated lumps of indigo are allowed to effloresce in a cask for some time, and when they become hard they are wiped and packed for exportation.

The other method of extracting the indigo from the plant, differs from that described only in the first operations. Instead of putting the plant into the vat when newly cut, it is spread out to dry in the sun for two days, and then thrashed to separate the leaves from the stems. The former are kept until they have changed from a green to a bluish-grey or lavender color, after which they are put into the first vat with warm water, and kept stirred till the leaves are so completely wetted as to sink. The liquor is then instantly let off into the beating vat, where it is treated as already described.

Berthollet, in narrating the procedure in the fermenting vat, gives the following opinion:—In the first, a fermentation is excited, in which the action of the atmosphere does not intervene, since an inflammable gas is evolved. There probably results from it some change in the composition of the coloring particles themselves, but especially the separation or destruction of a yellowish substance, which gave to the indigo a greenish tint, and rendered it susceptible of the chemical action of other bodies. This species of fermentation passes into destructive putrefaction, because the indigo has a composition analogous to that of animal matter.

Dr. Ure states, that from some experiments made upon the gases given off during fermentation, they were found, when taken about the middle of the operation, to be composed centesimally of 27·5 of carbonic acid gas, 5·8 of oxygen, and 66·7 of nitrogen; and towards the end of the process, they consisted of 40·5 of carbonic acid gas, 4·5 of oxygen, and 55 of nitrogen. No carbide of hydrogen seems to be disengaged. He adds that the fermenting leaves apparently convert the oxygen of the air into carbonic acid, and leave its nitrogen free. They also evolve a quantity of carbonic acid spontaneously. It will be observed, remarks Napier, that these two opinions are decidedly contradictory; the one says that the action of the atmosphere does not intervene, and that an inflammable gas is set free; the other, that there is no inflammable gas evolved, and that the air is apparently the principal agent in effecting the various changes. But when it is recollected that the leaves are all under the liquor, and kept so by the fixed position of the beams, there can be little contact between the fermenting leaves and the air, except that held by the water and among the leaves, and that of the plants themselves; hence the conversion of its oxygen into carbonic acid gas must be limited.

Sir Robert Kane says of this process:—After some time a kind of mucous fermentation sets in; carbonic acid, ammoniacal and hydrogen gases are evolved, and a yellow liquor is obtained, which holds the indigo dissolved. The theory of this action is, that by the putrefaction of the vegeto-animal matter of the leaves, the indigo is kept in the same white soluble condition in which it exists in the plant.

Dr. T. Thomson supposes that the indigo exists in the plant in union with another substance, which during fermentation is decomposed, and carbonic acid gas consequently evolved. To quote his own words:—The leaves of the indigofera yield a green infusion to hot water, and a green powder may be precipitated from it; but unless a fermentation has taken place, neither the color nor the properties have any resemblance to those of indigo. There is little doubt that in the leaves it exists in the state of white or *deoxidised indigo*, and that, during the fermentation, it combines with the requisite quantity of oxygen to convert it into *blue indigo*. The evolution of carbonic acid gas renders it not unlikely that the *white indigo* was in combination with some principle—probably of an alkaline nature—which was decomposed during the fermentation.

It is obvious from these discrepancies of opinion relative to the nature of the metamorphoses which occur during fermentation, that investigations have not been instituted into this part of the process to so full an extent as would seem to be required, and hypotheses advanced upon statements concerning the gases given off must be as unsatisfactory as they are hazardous. The supposition of Dr. Thomson, says Napier, and the Editor agrees with the opinion, appears to be best supported: deoxidised indigo readily unites with alkaline substances, and, as alkaloids generally contain nitrogen, the evolution of that gas either free, or in combination with hydrogen and oxygen, forming ammonia, can readily be credited. Napier suggests that indigo, when fully examined, may, like gallic acid, be found to be the result of some complicated decomposition, and not, as is now generally received, pre-existent in the vegetal.

The reactions which occur during the beating are more easily elucidated, and though this point, like most others, has had its quota of dubitable assertions, yet the discrepancies of the various statements are not so numerous. Dr. Ure says:—The object of the beating is threefold : first, it tends to disengage a great quantity of carbonic acid present in the fermented liquor; secondly, to give the newly developed indigo its requisite amount of oxygen by the most extensive exposure of its particles to the atmosphere; and, thirdly, to agglomerate the indigo in distinct flocks or granulations.

Manufacturers know well that sunshine aids in the separation of the indigo from the liquor. The absorption of oxygen, as the indigo is thrown down during the agitation, seems to be well established by direct experiment. From all these facts, however, no standard information regarding the changes occurring in the vat seems to be furnished. Indigo, whether in an oxidised or deoxidised state, is insoluble in water, and there must be some principle which retains it in solution previous to the beating. The only substances at present known as being capable of liquefying white or deoxidised indigo, are the alkalies and alkaline earths. But, says NAPIER, during such a generation and emission of carbonic acid gas, the existence of any known alkaloid capable of holding the indigo in solution is next to impossible, and results prove the contrary; for, while the acid is liberated, the indigo becomes insoluble, a result just the opposite of what one would conceive to occur in the presence of an alkaline substance, except it be supposed either that the carbonic acid arises from the decomposition of the alkaloid, or that it is evolved from *some substance which is being resolved into indigo.*

Indigo, as it occurs in commerce, is usually met with in cubical lumps or cakes, friable, more or less brittle, and of various shades of a peculiar deep-blue, passing into violet-purple. When rubbed with a smooth hard body, it acquires a beautiful glossy and cupreous appearance, and always affords, on grinding, an intensely blue powder. Its specific gravity is sometimes greater, but at other times less, than that of water; this depends principally on its admixture with, or freedom from, foreign matters, but also upon the treatment of the paste in the operations of boiling, pressing, and drying. The best samples are those which are lightest and most copper-colored.

CHEVREUL has so minutely described the numerous varieties of commercial indigo, as to preclude the necessity of presenting the reader with details of their physical appearance from any other source.

Indigoes prepared in Asia will first be noticed; they are from Bengal, Coromandel, Madras, Manilla, and Java.

The trade in Bengal indigo is chiefly carried on in Calcutta, and through the medium of the East India Company; its varieties are very numerous. The principal, commencing with those of the best quality, are the following:—1. The superfine or light blue. This is in a cubical form, light and friable, soft to the touch, of a clean fracture, and giving a beautiful copper color on being rubbed with the nail. 2. Superfine violet. 3. Superfine purple. 4. Fine violet, in color a little less brilliant than the superfine, and rather heavier. 5. Fine purple violet. 6. Good violet, somewhat heavier than the fourth quality. 7. Violet red. 8. Common violet. 9. Fine and good red, heavier than the preceding, and the hue of which borders decidedly on red. 10. Good red, of a firmer and more compact structure. 11. Fine copper-colored, redder, and still more dense. 12. Middling copper-colored. 13. Ordinary and low copper-colored; this is of a cupreous tinged blue or red, somewhat difficult to break.

Coromandel indigoes of the best quality correspond to those of Bengal of medium value, and are met with in square masses, having an even fracture, but are more difficult to break; indeed, these are harder to disrupture than any other variety. The inferior kinds are heavy, of a sandy feel, having a blue color bordering on green, grey, or even on black; they are not unfrequently found having a greenish-grey hue.

The productions of Madras have a grained rough fracture, and are of a cubical figure. The superior qualities have no rind, in form they somewhat resemble that of a *hat*, and are more light and friable than those of Coromandel. These kinds, when of the best quality, are very light, though not equal in this respect to the superfine blue of Bengal. The middling classes have a very slight copper tinge. The color of the inferior qualities is a dark or muddy blue, black, or even grey, and greenish.

The Manilla indigoes present the mark of the rushes upon which they have been dried. They are of a closer consistence and lighter hue than those of Madras, but not so compact as the produce of Bengal. The better qualities are often in flat and elongated masses, somewhat porous, and consequently light. Medium kinds are of a violet color, but are inferior to the violet of Bengal.

Java indigo occurs in flat square masses, sometimes of a lozenge shape. The superior qualities appear as fine as the blue, violet, or red indigoes of Bengal, but they are not so in reality.

Indigo prepared in Africa next come under consideration. They are from Egypt and Senegal:—

The superior classes of Egyptian indigo are superfine and fine violet blues. They are light, but their structure is not very compact, and they often contain sand. The squares are rather flatter than those of Bengal.

Senegal indigoes are of good quality, but contain more earthy matter than any others in the trade.

The indigo from America are those of Guatemala, Caraccas, Mexico, Brazil, Carolina, and the Antilles.

The indigoes of Guatemala, of the Caraccas, and of Mexico, are of various kinds. The best are of a bright blue color, remarkably light and fine. These are esteemed equal to the best Bengal. The inferior qualities are of a violet hue, but, in general, are more mixed than the Bengal kinds.

The Brazil indigoes are in small rectangular parallelopiped masses, or in irregular lumps, of a greenish-grey color externally, having a smooth fracture, a firm consistence, and a cupreous tint of greater or less brilliancy.

The Carolina product is in small square masses, having a grey exterior. The best qualities have a dull copper color, bordering on violet or blue. The common kinds are almost always of a greenish-blue; they are rarely found of a cupreous hue.

The principal varieties of indigo in commerce are the Bengal, the Caraccas, the Guatemala, the Madras, and the Manilla.

The buyer should be on his guard against certain defects, of greater or less consequence, and which depend on causes acting either on the indigo when already prepared, or else occurring during its preparation. The following are some of the characters to be borne in mind:—The large or small fracture; squares of indigo reduced by accident into lumps of variable size; fragments; squares abraded so as to be fine enough to pass through a sieve; sometimes, also, squares are met with which are readily broken, and which present a whitish kind of mouldiness in their interior; gritty lumps, throughout which are points presenting the appearance of granite; streaky masses, in which are layers of various shades of blue, placed one above the other, in the same square; pieces of a scorched appearance, which, on being sharply rubbed between the hands, are ground into small fragments, nearly black in color; sandy lumps, in the interior of which the eye can detect shining specks, which are nothing more than sand.

Indigo is insoluble in water, ether, hydrochoric acid, sulphuric acid in a dilute state, cold alcohol, and in ethereous and fat oils; but the latter liquids when boiling take up a small amount of it, which they deposit on cooling. Creosote has the property of dissolving it.

The commercial value of indigo is dependent upon the amount of pure indigo—indigo-blue—which the various kinds may contain: the average proportion is about fifty per cent. Chevreul prescribed a method for the rough analysis of indigo, by exposing it successively to the action of water, alcohol, and hydrochloric acid. One hundred parts of Guatemala indigo, thus treated, gave,

To water.......	Green matter combined with ammonia, Deoxidised indigo, Extract, Gum	12
To alcohol.....	Green matter, Resin, A trace of indigo	30
To hydrochloric acid......	Red resin,	6
	Carbonate of lime,	2
	Oxide of iron, Alumina	2
Residue........	Silicic acid,	3
	Pure indigo	45

Some chemists consider that the only method of accurately determining the value of this article consists in removing the various impurities by the successive action of dilute acid, caustic alkali, alcohol, and water, and then ascertaining the quantity of indigo-blue that remains, the ash being deducted in the usual manner. Others, again, prefer the process of reducing the indigo-blue by deoxidising agents, and afterwards precipitating and collecting it in the pure state. This method was adopted about the commencement of the present century by Pringle, who employed the well known materials, sulphate of iron and lime, as the reducing and dissolving agents, and separated the indigo-blue from the clarified solution with hydrochloric acid. The operations involved in this process are exceedingly tedious, and in consequence of the peculiar property which reduced indigo has of forming two distinct combinations with lime, the one soluble and the other insoluble, the results afforded by it are not always satisfactory.

Dana has recommended another method, based, however, on the same principle. It consists in boiling the indigo in caustic soda, and cautiously adding protochloride of tin until the indigo-blue is completely reduced and dissolved; the clear solution is then precipitated with bichromate of potassa, and the subsidence, being well washed with dilute hydrochloric acid, is dried and weighed.

Fritzche has suggested grape-sugar, alcohol, and caustic soda for the reduction and solution of the indigo-blue. His process appears, however, to be better adapted for the preparation of pure indigo than for testing its value; indeed, for the former of these purposes, Berzelius has spoken of it in the highest terms. It is as follows:—Four ounces of finely powdered indigo, and the same quantity of grape-sugar, or honey, are mixed with a little alcohol having a specific gravity of 0·860, and the whole is put into a bottle of ten pounds capacity; six ounces of a concentrated solution of caustic soda are then added, the bottle is filled up with hot alcohol, well stopped, shaken, and then set aside. After the lapse of some hours, the clear red fluid is siphoned from the insoluble deposit into another bottle, the mouth of which is loosely covered, so as to allow the admission of air. In the course of a few days the indigo-blue falls down, and, after having been separated, it is washed first with alcohol, and finally with hot water.

Chevreul's method of dyeing cotton until the indigo solution is exhausted, is, obviously, extremely objectionable

Reinsch, after trying various modes, prefers that of dissolving a grain and a half of the indigo in concentrated sulphuric acid, and estimating its value, comparatively, by the quantity of water required to reduce the color of the solution to a certain shade. This process, which is both simple and convenient, differs in no respect from that long since applied by Ure.

Labillardière determined the commercial value of indigo by means of an instrument to which he gave the name of *colorimeter*, and which consists of two perfectly cylindrical glass tubes, each closed at one end, about half an inch in diameter, and from thirteen to fourteen inches long. These must be made of the same glass, and of the same bore and thickness. At about five-sixths of their length from their closed ends, they are divided into two parts of equal capacity, the second half being graduated into one hundred divisions. The tubes are then placed in a small wooden box, through two contiguous openings in its upper part; immediately behind them, two square holes, or slits, corresponding to their diameters, are cut, whilst the other end of the box has an eye-hole, so that by holding the whole before the light, and looking at the tubes through the eye-hole, the difference of hue of the colored liquor put into the tubes may be easily appreciated. The inside of the box should be blackened.

The *modus operandi* is as follows:—Take a sample of each parcel of indigo to be examined, reduce them separately to a fine powder by triturating and sifting; weigh off twenty grains of each, and introduce that quantity into a small matrass perfectly clean and dry; pour upon it four hundred grains of sulphuric acid of specific gravity 1·845, and leave the whole exposed to a gentle heat of about 100° or 110° Fahr. for about an hour, shaking the vessel from time to time, in order to promote the solution. When this has occurred, and the menstruum has become cold, the whole is emptied into a large glass bottle capable of holding four pints, stirring it well with a glass rod; the matrass should be well rinsed with water, which is to be poured into the bottle, and more is added until the latter is completely filled up. Take now ten thousand grains of this liquor and pour them into a glass beaker, which should be left at rest for a few hours, so that any solid matter held in suspension may fully subside. The rest of the liquor, not being used, may be thrown away.

If several samples of indigo have to be tested, they must all be examined at the same time and in the same manner.

The clarified solutions are then poured into the respective colorimeter tubes till filled up to 0°; the latter are then introduced into the apertures in the box, and the shade is examined by looking at them through the eyehole opposite; if a difference in the depth of the color is observed, water is added to that which is the deeper of the two; the opening of the tube being well closed with the finger, the liquid is well shaken and the tube is replaced, water being added, if need be, until both correspond. By looking at the graduations to which water has been added, the operator knows at once the difference or relative tinctorial power of the two samples examined, for it is evident that the indigo which has required the greater quantity of water to reduce it to the same pitch or intensity of color as the other, is richer or of greater value.

Bolley proceeds in the following manner:—One gramme of indigo is rubbed to a fine powder in a porcelain mortar, about ten grammes of fuming sulphuric acid are poured over it, and the mixture left covered from six to eight hours, being occasionally stirred. After this time the whole is removed into a strong evaporating dish, containing two pounds of water; fifty grammes of strong hydrochloric acid are added, and the whole is heated to ebullition over a spirit or gas lamp. The water which escapes during the evaporation is from time to time replaced. A solution of chlorate of potassa is now made as follows:—One fourth of a gramme of the warm powdered dry salt is dissolved in one hundred grammes of water in a graduated cylinder capable of containing several decimètres of water. This quantity of chlorate suffices even for the very best kinds of indigo. At first, several decimètres of the solution may be added at once, but subsequently only one degree at a time, and the mixture boiled between every addition. The liquid passes from blue into green, brownish-green, and lastly into brownish-red. Any one who has once made the experiment will not fail to observe the right moment when to stop, that is, when the liquid has lost the last tint of greenish-brown, and turns reddish-brown. To insure certainty, it is well to make a mark with a glass rod, moistened in the gradually changing solution, upon a strip of white filtering paper.

The values might, by calculation, or a different arrangement of the apparatus, be reduced to those of pure indigo-blue; but that appears useless, as the latter is not an article of commerce, and the consumer or purchaser is satisfied when he has ascertained the value of the samples as compared with kinds known by him to be good.

An apparently simple, and not less ingenious method, proposed by Dr. **Penny**, is based upon the circumstance that indigo-blue, in presence of hydrochloric acid, is decolored by bichromate of potassa. This salt has long been used for discharging indigo-blue and other colors in the printing of textile fabrics, as well as for bleaching oils, fats, and various substances. In employing it for estimating the comparative value of commercial indigo, the necessary manipulations are extremely simple.

Ten grains of the sample, in very fine powder, are carefully triturated with two drachms, by measure, of fuming sulphuric acid, and the mixture, being excluded from the air, is allowed to digest, with occasional stirring, for twelve or fourteen hours. A flat-bottomed flask, with a lightly-fitting cork, is a very convenient vessel for this operation. A few fragments of broken glass should be thrown in to facilitate the contact of the indigo and acid during the agitation, thus preventing the aggregation of the former into small clots, which the acid of itself cannot penetrate. If a small capsule or testing glass be used, it should be covered, during the digestion, with an air-tight glass jar. It will also be found advantageous to place the mixture in a warm situation, say between 70° and 80°, so that the action of the acid may be fully developed; a higher temperature than this must be avoided, as sulphurous acid is liable to be produced, and the trial in consequence completely vitiated. Great care must be taken to insure the perfect solution of the indigo-blue in the acid. This being accomplished, the solution is poured slowly, with constant stirring, into a pint of water contained in a basin, and three-fourths of an ounce—fluid measure—of strong hydrochloric acid immediately added, the vessel being rinsed clean with water.

An alkalimeter of one hundred equal measures is now made up, in the usual way, with seven and a half grains of dry and pure bichromate of potassa, and the solution added in small successive portions to the diluted sulphate of indigo in the basin, until a drop of the mixture, on being placed on a white slab, or on bibulous paper, presents a distinct light brown or ochreous shade, unmixed with any blue or green. The process is then finished; the number of measures of bichromate used is read off, which shows the comparative value of the indigo subjected to the trial.

In applying the test drop to the bibulous paper, the best results are obtained by bringing the end of a glass rod into contact with the indigo solution, and then gently pressing it against the surface of the paper. The stain thus produced will be circular, and conveniently localised to a small space. By using bibulous paper, it will also be found much easier to recognise the last traces of the blue color than when a slab is employed, and the results, when dry, may be preserved unchanged for reference or comparison.

It is advisable to keep the indigo solution gently heated while the test-liquor is being added; and it is essentially necessary that the mixture should be well stirred after each addition. Several measures of the test-liquors may at first be poured in without risk of error, but, towards the conclusion, the manipulation must be slow and careful, as one or two drops will then be found to produce a very decided effect. The characteristic changes of color which the mixture undergoes will distinctly indicate the approach of the process towards completion. The blue shade of the solution gradually diminishes in intensity, becoming perceptibly lighter and lighter, after a time acquiring a greenish tinge, which soon changes to greenish-brown, and almost immediately to light ochre brown.

This process, like many others apparently simple in description, is, so far as experience goes, not a reliable one in the hands of the mere practical man; it has often been tried, and as often laid aside with feelings of disappointment from the difficulty of finding the point of decoloration, and the deepening of the color by time, *et cetera.*

SCHLUMBERGER'S test consists in dissolving the indigo in fuming sulphuric acid—Nordhausen oil of vitriol—and decoloring the solution, previously diluted with much water, by chloroxide of calcium—bleaching powder—as this acts only on the blue coloring substance, and not at the same time on the various other bodies which indigo contains. The quantity of bleaching powder requisite to produce decoloration accurately agrees, as will be subsequently seen, with the amount of tinctorial matter.

The operations are as follow:—A portion of pure indigo, or indigo-blue, is prepared by removing the scum which is continually found on the *blue vat,* treating it with an excess of dilute hydrochloric acid, washing the deposit until all soluble parts have been removed, then drying and preserving it in well-closed bottles to protect it from all changes in the moist state. When no blue vats are at hand, a mixture is made of three parts of newly-slaked lime, three parts of sulphate of iron, one of indigo rubbed fine with water, and fifty of water. These are frequently stirred for some hours and left to subside, so that the clear liquid may be poured off; this is then violently agitated in order to bring it into contact with the atmosphere, and cause the separation of the whole of the indigo. The precipitate thus obtained is treated with dilute hydrochloric acid in the same manner as is described for the blue vat. In all subsequent experiments, this pure indigo serves as a standard of comparison with the results which the various kinds of indigo submitted to the test afford, and taking the pure indigo as one hundred, the value of the tested indigo is expressed by numbers which indicate the per centage of pure coloring matter. In each case the standard indigo is used for comparison with that of commerce, as it is then not requisite to determine previously the amount of chloroxide of calcium in solution, besides which the experiment is more accurate. In this instance the causes of the differences in the results depend on circumstances, which always remain the same whether the standard indigo is employed, or indigo, the purity of which is unknown. One gramme of each kind is weighed off, which must be finely ground. This is placed in a dish, and twelve grammes of fuming sulphuric acid added to it by means of a graduated pipette. The mixture is now rubbed together, the dish placed for four hours at a temperature of from 122° to 140°; or, what is preferable, for the sake of accuracy, it is transferred, well covered, to a place in which the temperature is about 68° to 78°.

Meantime as many glasses—each holding about a quart—as there are sulphate solutions, are filled with distilled water, and to each sample of indigo is added its equal volume of water from the glass. The liquids become warm, upon which they are well stirred again; water is then gradually added until the vessel is full, when the whole is poured into the glass, and the dish washed with a portion of the water. A solution of bleaching powder is now prepared, of 2° Twaddle—specific gravity 1·010—in strength, and a given quantity, say ten graduations of the alkalimeter, taken.

The well-stirred blue solution of the sulphate of indigo is now measured in a burette, and a portion poured into a dish, agitated thoroughly, and the entire quantity of the bleaching powder contained in the measure added at once. If the liquid immediately assumes a yellow color, it is a sign of an excess of the decoloring agent, and sulphate of indigo is added by degrees until a faint olive-green hue is obtained. The experiment is now repeated, and the quantity of chloroxide of calcium, which had been found necessary in the first case, added to the quantity of sulphate of indigo; so that with one single mixing, there being neither an excess of chloroxide nor sulphate of indigo, the liquid acquires that tint at once. But when, after the first mixture, the menstruum has retained a blue color, which is a sign of an excess of the sulphate of indigo, fewer degrees of it are taken, until the requisite tint has likewise been attained with a single mixing.

When the several indigoes have been treated in this manner, the following calculation is made to obtain the true value of the sample which has been examined; the goodness of the indigo being in inverse ratio to the quality of sulphate employed.

Suppose it were found that *pure* indigo required fifty-four parts of its sulphate solution to be decolored by the fixed quantity of bleaching powder, and that, on the other hand, the indigo under examination required sixty-four parts of its sulphate solution; then, according to the proportion,

$$64 : 54 :: 100 : x = \frac{100 \times 54}{64}$$

or 84·4, which indicates the quantity of indigo-blue contained in one hundred parts of the sample examined.

It is important, for the accuracy of the experiment, that the pure indigo, and the various kinds submitted to the test, should be equally moist, and it is therefore requisite to enclose all the samples, as soon as they are taken out of the chests, in stoppled bottles, to prevent any difference in the amount of moisture previous to weighing. When a chest contains several kinds of indigo, which exhibit only a slight variation in their tints, a few pieces are selected from the several lots, powdered together, and the mean result taken as the correct one. But when, as often happens, a chest contains pieces of indigo of entirely different hues, it is best to examine the mixed sorts separately.

SCHLUMBERGER dilutes both the solution of sulphate of indigo and that of the bleaching powder, since the experiment in this manner is less exposed to error than when concentrated menstrua are operated upon; besides, it is easier when the liquid is only faint blue to distinguish when the addition must be discontinued.

Impure water, or such as contains salts of lime, produces a more or less considerable precipitate of the blue substance, mixed with sulphate of indigo; it is, therefore, necessary to employ distilled water.

The purer the indigo, and the more complete its solution, the easier is it to ascertain the last stage of decoloration, or the point at which the test is completed; and in this case it is evident how sensitive the reaction of the bleaching powder is on the indigo; for a solution of the latter, to which an excess of chloroxide of calcium has been added, and which is therefore yellow, is rendered blue by a single degree of the indigo solution, a proof that this method will indicate half a per cent. In the commercial kinds of indigo it is less easy to fix the point at which decoloration must be discontinued, for in this case the bleached liquid assumes an olive hue, and from two to three degrees of the indigo solution must be added to change the yellow color into the blue.

The author of this method prefers taking a fixed quantity of chloroxide of calcium, and varying that of the sulphate of indigo, to making the latter a fixed quantity, and allowing the decoloring agent to be diminished or increased, from its being possible to dilute the indigo solution with much water, and so render the quantity of matter in each measure of it so small as will necessarily cause the saturation of the bleaching liquor to be approached by minute and delicate portions.

WITTSTEIN advocates the use of deoxidation tests above all others, and considers that any discredit into which it has fallen, is the result of unfounded prejudice. He also objects to the use of sulphuric acid as a solvent of indigo in testing, as that acid takes up other constituents of the indigo, and, at least, it is only a comparative test, and argues that the reduction test is not only a comparative, but an absolute and tangible result, when a few necessary precautions are taken, and gives the following directions:—

Ten grains of indigo are rubbed with water in a porcelain mortar; to this, twenty grains of hydrate of potassa are added, together with a few drops of water—the trituration being continued—and then forty grains of sulphate of iron. The mass is mixed with water, so as to form a thick paste, and introduced into a six ounce stoppered bottle, which has been previously weighed; the mortar should then be rinsed, and the bottle nearly filled up with water. After inserting the stopper, the whole is weighed, and well shaken for some time. After the lapse of a few hours, the indigo is deoxidised and dissolved. The mixture is then allowed to settle, the clear liquid is poured into a glass cylinder as completely as possible, and the bottle again weighed. The liquid is now treated with hydrochloric acid, the blue precipitate collected upon a weighed filter, washed with water, dried and weighed. By means of a proportion, it may be ascertained how much indigo-blue is contained in the indigo taken: if, for instance, the contents of the bottle weighed 3140 grains, the residue left on decantation, 535 grains, and the 2605 grains of clear liquor yielded 2·5 grains of indigo-blue; then,

$$2605 : 3140 :: 2{\cdot}5 : = 3{\cdot}01;$$

consequently, the indigo examined would contain 30·1 per cent. of pure coloring matter.

BERZELIUS, in 1827, made an investigation of indigo, and resolved it into four distinct bodies—*gluten;* a *brown matter*, having an apparent resemblance to extract; a *red substance* which, when heated in a close vessel, affords a grey sublimate; lastly, *indigo-blue.*

The matter by him termed gluten is dissolved both by alcohol and water: it was procured by digesting powdered indigo in dilute sulphuric acid, filtering the menstruum, evaporating it to dryness, and macerating the residue in alcohol.

The brown substance was taken up from the indigo—freed by the above procedure from gluten—by potassa, and was precipitated by sulphuric acid.

The indigo, thus acted upon by the acid and by potassa, was digested in alcohol, which abstracted a red principle, soluble in concentrated sulphuric and in nitric acids, but left intact by water and by alkalies, and which, when heated *in vacuo*, yielded a grey crystalline sublimate.

The residue, after these operations, is, with the exception of a small quantity of silicic acid, the true tinctorial matter of indigo—indigo-blue—and is the principle which affords a purple vapor and sublimate when indigo is heated.

In order to obtain perfectly pure indigo-blue, BERZELIUS treats the commercial product successively with hydrochloric acid, weak solution of potassa, and hot alcohol, to remove the foreign matters above mentioned; the remaining indigo-blue is then thoroughly mixed with twice its weight of freshly-slaked lime, and the mixture put into a bottle capable of holding one hundred and fifty times the quantity of the substance operated on; the bottle is then filled up with boiling water, and four parts of crystallized protosulphate of iron added for every three of indigo; it is then securely stopped, and having been thoroughly agitated, is set aside for several hours. In this way the indigo-blue, which is insoluble, is converted into indigo-white, which dissolves in the lime water, producing a yellow liquor, which is then poured off, mixed with dilute hydrochloric acid, and left for a long time exposed to air; the acid retains the lime and other substances in solution, while the indigo-blue is deposited, and may be freed from hydrochloric acid and chloride of calcium by washing in water.

If indigo-blue be heated to about 550°, it gives off beautiful reddish-violet fumes, which adhere to the sides of the vessel, or to the upper surface of the resulting charcoal, in long needle-like crystals. WALTER CRUM of Glasgow, whose investigations have materially elucidated the chemical nature and properties of indigo, uses for its sublimation two shallow platinum capsules about three inches in diameter, and of such depth that when placed together with their concave surfaces inwards, they are about three-eighths of an inch asunder in the centre. In the middle of the lower capsule are placed about ten grains of coarsely pulverised indigo, the cover is put on, and the flame of a spirit-lamp cautiously applied; vapor is seen disengaged with a sibilant noise; when this discontinues, the heat is removed, and the whole allowed to cool. The sublimed indigo will be found, in a crystalline state, principally upon the inner surface of the cover, though a little will remain upon the charred matter. In this manner from eighteen to twenty per cent. of the indigo employed were obtained.

Taylor's process, by which seventeen or eighteen per cent. has been procured, is as follows.—

A quantity of indigo is reduced to powder, mixed with about half its weight of sulphate of lime, and so much water added as will bring the whole to a thin paste. This is spread evenly, in the form of a strip about two inches broad, upon an iron plate, to the depth of one-eighth of an inch, and allowed to remain exposed to the air, or to a gentle heat, till it is tolerably dry. If the heat of a spirit-lamp be now applied to the under-part of the plate, fumes possessing a disgusting odor are evolved, and in a few minutes the indigo is covered with a dense purple-red vapor, which condenses into brilliant flattened prisms or plates, of an intense copper color, forming a thick velvet-like coating over the surface immediately exposed to heat. When this ceases to appear the heat is withdrawn, and when cold, the sublimed crystals may be readily swept off, without in the least disturbing the subjacent mass.

According to Crum, the processes of Berzelius and Fritzche yield pure indigo of a deep blue, but, at the same time, cupreous hue, and not unfrequently having a slightly crystalline appearance. When obtained, on the contrary, by means of heat, it forms flat needles and four-sided prisms, which, when seen at a particular angle, have a peculiar and intense copper color, but when lying in heaps, are of a rich brown. Occasionally the crystals are in broad, thin plates, which, when viewed by transmitted light, are of a splendid blue. The points at which it fuses, sublimes, and is decomposed, approach very nearly to each other. Its vapors somewhat resemble those of iodine; they are translucent, and possess a fine reddish-violet tint. When the crystals of indigo-blue are subjected to heat in communication with the atmosphere, they sublime without residue, in close vessels, as the temperature rises, the fumes acquire a scarlet hue, and then become orange-colored; a small quantity of a *peculiar basic empyreumatic oil*—anilin—is also formed, and carbonaceous matter deposited. Sublimed indigo-blue has a specific gravity of 1·35.

The composition of pure indigo was first ascertained by Crum, and his results have been confirmed by Dumas, as also by Erdmann and Laurent. Its formula, as generally accepted, and as deduced from the analyses of the above chemists, is $C_{16} H_5 O_2 N$.

		Centesimally represented.				
	At. weight.	Theory.	Crum.	Dumas.	Erdmann.	Laurent.
16 Eqs. Carbon,....	96	73·28	73·22	73·28	73·99	73·30
5 Eqs. Hydrogen,..	5	3·82	2·92	3·82	3·80	3·88
2 Eqs. Oxygen,....	16	12·21	12·60	12·21	11·56	22·82
1 Eq. Nitrogen,..	14	10·69	11·26	10·69	10·65	
1 Eq. Indigo-blue,	131	100·00	100·00	100·00	100·00	100·00

Indigo-blue is tasteless and inodorous, and is perfectly neutral, giving neither acid nor alkaline reaction. It is completely left intact by water and ether; a trace of it is abstracted by boiling alcohol. Hot olive oil and turpentine acquire from it a blue tint, but on attaining the temperature of the atmosphere, the fractional portion which they had seemingly dissolved, is deposited. Dilute acids and solutions of alkali have no effect upon it.

If pure indigo be brought into contact with deoxidising agents, it is rendered white, and has the new property of dissolving in alkalies. Phosphorus, sodium, calcium, phosphites, sulphites, sulphides of potassium, *et cetera*, protoxides of iron and tin, sugar, starch, tannic acid, *et cetera*, from their attraction for oxygen, all possess this attribute.

Liebig obtains *indigo-white* by adding hydrochloric acid to the yellow liquor procured by the action of lime and protosulphate of iron upon common indigo and water, preventing access of air both before and after the addition. The precipitate is well washed with newly-boiled water, or with a dilute solution of sulphurous acid, then drained as rapidly as possible on a filter, and dried *in vacuo*.

Berzelius siphons the yellow menstruum above mentioned, into a stoppered bottle previously filled with hydrogen or carbonic acid gas, and containing some acetic or dilute hydrochloric acid, the siphon itself being previously filled with water deprived of air. Under these circumstances, a white, flocculent, and often crystalline precipitate falls; it should be carefully excluded from contact with the atmosphere, and allowed to settle; the supernatant liquid must then be decanted, the subsidence collected upon a filter in an atmosphere of hydrogen or of carbonic acid, edulcorated with water freed from air, pressed in folds of bibulous paper, and dried *in vacuo*.

The composition of indigo-blue, from the analyses already cited, is represented by $C_{16} H_5 O_2 N$; that of indigo-white, according to Dumas, the accuracy of whose results has never been questioned, is $C_{16} H_6 O_2 N$; so that the only difference between them is one equivalent of hydrogen. With regard to their rational formulæ, two distinct but ingenious hypotheses have been suggested. In the first of these, *indigo-white is accepted as the hydride of indigo-blue*, and the relation has been compared to that of benzil and its hydride; thus—

Oxide of benzil, $C_{14} H_5 O_2$,	Indigo-blue, $C_{16} H_5 O_2 N$.
Hydride of oxide of benzil, H, $C_{14} H_5 O_2$..........	Indigo-white, H, $C_{16} H_5 O_2 N$.

Liebig stands at the head of those who are favorable to the other view, which infers that *indigo-white is the hydrate of a body having one equivalent less oxygen than indigo-blue;* in other words, a compound $C_{16} H_5 O N$ is supposed to be a base, of which indigo-blue is an oxide, and indigo-white a hydrate; thus—

Indigo-blue,................. $C_{16} H_5 O N + O$.
Indigo-white,............... $C_{16} H_5 O N + H O$.

The production of indigo-white by the agency of grape-sugar strongly supports the latter inference, for were indigo-white a hydride of indigo-blue, it could only be formed, in this instance, by the decomposition of water, the hydrogen of which would combine with the indigo-blue, while its oxygen would again unite with the hydrogen of the sugar, and it is highly improbable that oxygen should separate from the hydrogen of one body to unite with it in another.

It is further obvious, says **Brande**, that as concerns these compounds, a common radical, *anyl*—$C_{16} H_5 N =$ An—may be assumed as their basis. In such case, indigo-white would be a *hydrate of the protoxide of anyl*, An O, H O; while indigo-blue would be a *binoxide of anyl*, An O_2.

Indigo-white is insoluble in water and in dilute acids, but dissolves in alcohol, ether, and alkalies, to which it imparts a yellow tinge; the solutions, if exposed to the air, gradually combining with oxygen, and depositing indigo-blue. When pure, it would be perfectly white, but as known hitherto, it has always a greenish or bluish tint. When moist, it rapidly passes, under atmospheric influence, into blue; and when exsiccated acquires that hue to a greater or less degree. Even *in vacuo* this change slightly occurs, owing probably to the air still retained in the pores of the substance. When slowly heated in the air, it speedily becomes dark purple, and is converted into indigo-blue.

The solutions of indigo-white in alkalies cause precipitates with many metallic salts. These deposits, when not blue at first, become so on exposure. According to **Runge**, the subsidence occasioned by indigo-white in solutions of sesquioxide of iron, affords, when heated, a green sublimate; that formed with salts of oxide of copper being yellow; with silver-salts, orange-yellow; and the one with binoxide of mercury, grass-green; all of them having a crystalline texture. These results require a more minute investigation, especially as they differ from those of other chemists.

If an aluminous menstruum be precipitated by an alkaline solution of indigo-white, the deposit readily becomes blue, and if collected on a filter and exsiccated, it glitters as if crystalline: when heated, indigo-blue sublimes, and the residuary alumina possesses a greenish tint. Compounds of indigo-white with metallic oxides are best procured by adding the crystalline salts of the latter to saturated alkaline solutions of the former, in entirely filled and well-stoppered bottles. According to **Löwig**, the lead compound obtained in this way is somewhat crystalline, deflagrates slightly when heated, and leaves metallic lead. The combination with tin gives a sublimate of indigo-blue. The precipitates with manganese and cobalt are green, and afford no sublimate.

The action of sulphuric acid on indigo-blue gives rise to a number of beautiful and highly interesting bodies. First among these stands *hyposulphoindigotic acid*, synonymous with *sulphindigotic acid*, and with the *sulphindylic acid* of **Dumas**, which may be obtained by digesting, for three days, one part of indigo-blue with fifteen of concentrated sulphuric acid in a stoppled bottle, and at a temperature not lower than 120°, but which should not be allowed to exceed 140°. A deep blue solution, without any evolution of sulphurous acid, results; this is perfectly miscible with water, and if the proportions above-mentioned have been maintained in the manipulation, there is no sediment. When evaporated, the acid remains as a dark-blue substance, deliquescent, and possessed of a singular odor; with water and alcohol it gives an intense blue solution, having a sour and slightly astringent taste. Woollen cloth steeped in the diluted menstruum abstracts the color, becoming effectually dyed. By macerating the wool, after this treatment, in a solution of carbonate of ammonia, hyposulphoindigotate of ammonia is obtained, whence other salts of the colored acid may be procured. For the preparation of the potassa compound, **Dumas** gives the following recipe:—

A strong solution of acetate of potassa is poured into an aqueous one of the concentrated blue liquor, which occasions a deposit of sulphate and sulphoindigotate of the alkali; the whole is filtered through pure bibulous paper placed upon a remnant of linen cloth, and percolation allowed to proceed for twenty-four hours; the filtrate ought to be perfectly clear and almost devoid of color. The subsidence is then collected, agitated in a concentrated solution of acetate of potassa, and the filtration repeated; the sulphate is thus separated from the blue compound, but as a portion of the former still remains in admixture, the precipitate is again thoroughly diffused in acetate of potassa, and the whole is replaced on the strainer. The acetate is now removed by edulcoration with alcohol, and, finally, the salt is desiccated *in vacuo*. The formula generally accepted for sulphoindigotic acid is H O, $C_{16} H_4 O_2 N + S_2 O_5$; that assigned to its potassa compound being K O, $C_{16} H_4 O_2 N$, $S_2 O_5$, in which the indigo is dispossessed of one atom of hydrogen, while the two equivalents of sulphuric acid have lost one of oxygen. **Dumas**, however, gives it the formula of a double sulphate, $C_{16} H_4 O N$, $S O_3 +$ K O, $S O_3$, and institutes an analogy between alcohol and indigo-blue; thus, the latter being represented as H O, $C_{16} H_4 O N$, the body $C_{16} H_4 O N$ would be the counterpart of oxide of ethyl. His views, however, are far-fetched, are not supported by the chemical relations of the substances in question, and, moreover, are less obvious and convenient than those previously given.

Zinc or iron deprives an aqueous solution of hyposulphoindigotic acid of its color, without causing any hydrogen to be evolved; the usual hue returns, however, on withdrawal of the metal and exposure to the air. It is not altered in any way by sulphide of hydrogen at ordinary temperatures, but when heated to 120° the color disappears, and a deposit of sulphur occurs. All the substances which reduce indigo-blue to indigo-white, have a corresponding action on this acid.

Salts of hyposulphoindigotic acid are most advantageously procured by direct saturation; by transmitted light they are generally of a red color. When protosulphate of iron is dissolved in a solution of a neutral hyposulphoindigotate, the tinge is not altered, nor is it affected when part of the oxide is thrown down by alkali, but when it is entirely precipitated, and especially when a slight quantity of alkali has been added in excess, decoloration immediately takes place. The blue again reverts on saturating with an acid. Common sulphates and the generality of salts cause deposits in solutions of hyposulphoindigotates of alkali, which are only sparingly soluble in alcohol. If the blue acid be slightly supersaturated with carbonate of potassa, the mixture assumes a gelatinous aspect; the same effect is secured by adding sulphate and the other salts of potassa —with the exception of the nitrate—to a mixture of hyposulphoindigotic with sulphuric acid; the resulting subsidence when desiccated shrinks, and acquires a cupreous hue. Boiling water dissolves the potassa salt, but deposits the greater portion of it on cooling: the ammonia and soda compounds bear a great similarity to that of potassa. Water, when cold, with difficulty dissolves the hyposulphoindigotates of lime and of baryta, but, when hot, forms with them blue menstrua, which throw down the greater part of the salts on cooling.

When one part of indigo is dissolved in eight parts of oil of vitriol, the addition of water separates a purple powder. The filtrate from this contains, according to BERZELIUS, sulphoindigotic and hyposulphoindigotic acid, while the deposit just mentioned forms a third—*sulphopurpuric*, the *phenicin* of CRUM. This must be immediately edulcorated with water to which a little hydrochloric acid has been added, till every trace of free sulphuric acid has disappeared, and then cautiously exsiccated. DUMAS recommends drying it in an oil bath, between the temperatures of 356° and 392°. If the heat is not carried beyond the former degree, moisture is retained, while at the latter decomposition commences.

Sulphopurpuric acid readily dissolves in water and in alcohol. If digested in sulphuric acid, it is converted into hyposulphoindigotic acid. According to the last-named chemist, it is composed of two equivalents of indigo-blue and two of sulphuric acid, which together unite with one atom of base. Its centesimal constitution, when anhydrous, is as under:—

	At. weight.	Theory.	Dumas
32 Eqs. Carbon,............	192 ..	56·14 ..	56·5
10 Eqs. Hydrogen,..........	10 ..	2·93 ..	2·9
4 Eqs. Oxygen,............	32 ..	9·35 ..	7·4
2 Eqs. Nitrogen,...........	28 ..	8·19 ..	8·1
2 Eqs. Sulphuric acid,......	80 ..	23·39 ..	23·1
1 Eq. Sulphopurpuric acid,..	342	100·00	100·0

Salts of sulphopurpuric acid may be prepared by adding its aqueous solution to that of any salt; the acid of the latter is liberated, and the sulphopurpurate of the base deposited. In general, the appearance of the salts resembles that of the acid: they vary in solubility, according to the bases employed, those of soda and ammonia being most readily liquefied. The compounds of sulphopurpuric acid with lime, magnesia, protoxide of iron, and oxides of copper and zinc, are so far insoluble as to communicate to water a pale-blue tinge only. They dissolve better in alcohol than in water, and have, in common with indigo-blue, the attribute of being decolored by deoxidising agents, and re-acquiring color on exposure to atmospheric influence.

The whole subject of the compounds of indigo with acids is still exceedingly obscure, and must continue so till additional researches shall have been vigorously and faithfully executed.

Notwithstanding, however, the number and intricacy of the bodies produced by the action of sulphuric acid on this composite dye-stuff—which, at the same time, are highly interesting—the principles afforded by its oxidation are still more numerous, and full as many difficulties have hitherto attended, and still seem likely to accompany, the investigations into their composition and various properties.

Isatin is one of the products obtained when indigo is oxidised by means of chromic or nitric acid. It seems to have been simultaneously discovered by ERDMANN and by LAURENT.

To procure it, indigo, mixed with water to the consistence of a thin paste, is gently warmed, and nitric acid added in small quantities—allowing the effervescence caused by each addition to cease before adding the next portion—till the blue color is destroyed, avoiding, however, the presence of more acid than is necessary for this purpose. A brown deposit is afforded. The mass is now boiled with a large quantity of water, and the filtrate on cooling deposits isatin in crystals. These are purified by dissolving them in potassa, and adding hydrochloric acid as long as it causes a black or brown subsidence of resinous matter. When a filtered portion gives, with hydrochloric acid, a pure bright-red precipitate, the whole is passed through bibulous paper and mixed with the acid, which causes the isatin to fall in crystals. This is to be well washed with cold water, and crystallized from a hot alcoholic solution.

When chromic acid is employed, its dilute aqueous solution is gradually added to pulverised indigo; the mixture is heated nearly to its boiling point, and a brown liquid is obtained. The chromic acid should only be of such strength as freely to dissolve the indigo; for, if it be too strong, carbonic acid is evolved, oxide of chromium is precipitated, and isatin is not formed. The brown menstruum should be filtered whilst hot, and the isatin crystallizes on cooling.

Isatin, thus prepared, forms brilliant hyacinth-red or reddish-brown prismatic crystals which are inodorous, dissolving scantily in cold, but more abundantly in hot water; readily soluble in alcohol, but less so in ether. The alcoholic menstruum imparts a peculiarly disagreeable and permanent odor to the cuticle. When isatin is subjected to heat in a tube, a portion of it sublimes, but the greater part undergoes decomposition, and a difficultly combustible charcoal remains. When heated in the air, fusion takes place, a suffocating odor is exhaled, a brilliant flame appears, and a considerable amount of carbonaceous matter is left. Isatin dissolves in solutions of potassa and of ammonia, as also in those of sulphides of hydrogen and ammonium, giving rise to a host of compounds of peculiar character, but with too little promise of utility in the arts to warrant their special enumeration.

The centesimal composition of isatin is—

	At. weight.	Theory.	Laurent.	Erdmann
16 Eqs. Carbon,......	96 ..	65·30 ..	65·2 ..	65·3
5 Eqs. Hydrogen,....	5 ..	3·40 ..	3·5 ..	3·4
4 Eqs. Oxygen,......	32 ..	21·77 ..	21·8	31·3
1 Eq. Nitrogen,....	14 ..	9·53 ..	9·5	
1 Eq. Isatin,........	147	100·00	100·0	100·0

Isatin is, therefore, indigo plus two equivalents of oxygen, or $C_{16}\,H_5\,O_2\,N + O_2 = C_{16}\,H_5\,O_4\,N$.

The purple menstruum which isatin forms with caustic potassa becomes yellow when heated, and furnishes, on evaporation, a crystalline salt, in small hard prisms—isatinate of potassa. When this is dissolved, and acetate of lead added, a white precipitate falls, which, diffused through water and decomposed by sulphide of hydrogen, yields a colorless acid solution: this, if allowed to evaporate spontaneously *in vacuo*, leaves a white and scarcely crystalline powder, which is *hydrated isatinic* acid. If boiled in water, it is resolved into water and isatin, which is deposited, on the cooling of the menstruum, in a crystalline state, the latter having acquired a brown color. Most of the isatinates are insoluble, or only dissolve with difficulty in water, and may be procured, as just described, by the double decomposition of the potassa salt. Anhydrous isatinate of silver is composed of—

		Centesimally.		
	At. weight.	Theory.	Erdmann.	Laurent.
16 Eqs. Carbon, ...	96	35·29	35·18	35·22
6 Eqs. Hydrogen, ...	6	2·20	2·03	2·48
5 Eqs. Oxygen, ...	40	14·71	22·51	62·30
1 Eq. Nitrogen, ...	14	5·15		
1 Eq. Oxide of silver, ..	116	42·65	40·28	
1 Eq. Isatinate of silver,	272	100·00	100·00	100·00

Laurent gives the formula of crystallized isatinate of silver, procured by mixing solutions of nitrate of silver and isatinate of potassa in a state of ebullition, as $Ag\,O,\ C_{16}\,H_6\,O_6\,N,\ H\,O$.

According to **Erdmann**, when isatin is dissolved in sulphide of ammonium by means of heat, there is deposited on cooling a yellowish-white powder, *not crystalline*, which he terms *isatyd*. **Laurent** obtained it previous to the year 1844, by adding a little sulphide of ammonium to a hot alcoholic solution of isatin, and allowing the mixture to rest in a stoppered phial; small white crystals soon formed, and in the course of eight days a grey deposit occurred: this was separated, washed with alcohol, and was found on microscopical examination to consist of minute prismatic and octohedral crystals; the latter were sulphur, and were removed by sulphide of carbon, in which they are soluble, while those of isatyd are found not to possess this characteristic.

More lately, the same chemist has devised an ingenious way of isolating it:—Pulverised isatin is heated in a flask, with a large quantity of water, a little sulphuric acid, and a fragment of pure zinc. The isatin gradually dissolves, seizing the nascent hydrogen, and being transformed into isatyd, which is precipitated as a crystalline powder. This is then separated, washed with and dissolved in alcohol, from which it is permitted to crystallize.

Isatyd is insoluble in water, and only sparingly dissolves in boiling alcohol and ether, which deposit it in microscopic crystals on cooling. It dissolves in alkalies with a dark-red color, which, on the application of heat, changes to yellow. The solution in potassa, according to **Erdmann**, deposits crystals, and gives, when treated with hydrochloric acid, a flocculent yellow precipitate.

Its analysis gave the following results, showing it to be isatin plus one equivalent of hydrogen, and bearing the same relation to isatin as indigo-white to indigo-blue.

		Centesimally represented.	
	At. weight	Theory.	Laurent.
16 Eqs. Carbon, ...	96	64·86	65·11
6 Eqs. Hydrogen, ...	6	4·06	4·13
4 Eqs. Oxygen, ...	32	21·62	21·26
1 Eq. Nitrogen, ...	14	9·46	9·50
1 Eq. Isatyd, ...	148	100·00	100·00

When chlorine is passed through a solution of isatin, or through water in which indigo is held in suspension, two new substitution compounds are formed, which were termed by **Laurent**, in accordance with his nomenclatural rules, *chlorisatinase* and *chlorisatinese;* **Erdmann**, however, more consistently with the methods of designation now generally adopted, gave them the appellations, *chlorisatin* and *bichlorisatin*, which are quite as explanatory. If, when the action of the chlorine on the indigo and water has been carried to the fullest extent, the crude product be distilled, volatile substances and water pass over, the former crystallizing in the neck of the retort and in the receiver, a mixture of chlorisatin and bichlorisatin remaining. These may be separated by means of alcohol in a state of ebullition; the chlorisatin, being more insoluble than the accompanying principle, deposits on cooling. By repeating the solutions in, and crystallizations from alcohol, they may be very effectively disunited and purified.

Chlorisatin, $C_{16}\left\{\begin{matrix}H\\Cl\end{matrix}\right.O_4N$, forms transparent orange-yellow four-sided prisms, isomorphous with isatin, and in all respects very analogous to it. One hundred parts of alcohol, of 0·830 specific gravity, dissolve 0·45 of chlorisatin, forming a dark orange-colored menstruum, neither acid nor alkaline, and which communicates to the skin a disagreeable and adherent odor. Chlorisatin is inodorous, bitter, almost insoluble in cold, but abundantly dissolving in hot water. It bears a heat of 320° without undergoing decomposition; at temperatures more elevated, fumes similar to those of burning indigo are evolved, and it ignites.

If dissolved in warm aqua potassæ, crystals of *chlorisatinate* of the alkali form, the chlorisatin by combination with one atom of water having been converted into *chlorisatinic acid*, thus:—

$$\underbrace{C_{16}\left\{\begin{matrix}H_4\\Cl\end{matrix}\right.O_4\,N}_{\text{Chlorisatin.}} + \underbrace{H\,O}_{\text{Water.}} = \underbrace{C_{16}\left.\begin{matrix}\\\end{matrix}\right\}\begin{matrix}H_5\\Cl\end{matrix}O_5\,N}_{\text{Chlorisatinic acid.}}$$

The principle, *bichlorisatin*, remains in the alcoholic menstruum after the deposition of chlorisatin, than which it is more soluble, and consequently not so crystallizable. When its purification has been effected by redissolving in, and crystallizing from alcohol, it forms brilliant pink needles. With weak solution of potassa, it forms, at first, a deep-red liquid, which, on the application of heat, changes to yellow, and yields crystalline scales of that color, composed of the alkaline base and bichlorisatinic acid.

The formula of bichlorisatin is $C_{16}\left\{\begin{matrix}H_3\\Cl_2\end{matrix}\right.O_4\,N$, and in the change just noticed, it—like chlorisatin—unites with water, and the formula of the resulting acid is, according to **Laurent**, $C_{16}\left\{\begin{matrix}H_4\\Cl_2\end{matrix}\right.O_5\,N$. The acid may be separated from the potassa salt by stronger acids, as a yellow powder, which, when dissolved and warmed, is resolved into bichlorisatin and water.

Bromine acts on isatin, and forms two bodies, *bromisatin* and *bibromisatin*, in every respect analogous with the bodies resulting from the action of chlorine on isatin; the formulæ are as follow :—

Bromisatin, ...$C_{16}\left\{\begin{matrix}H_4\\Br\end{matrix}\right. O_4\,N$

Bromisatinic acid,..............$C_{16}\left\{\begin{matrix}H_5\\Br\end{matrix}\right. O_5\,N$

Bibromisatin,.....................$C_{16}\left\{\begin{matrix}H_3\\Br_2\end{matrix}\right. O_4\,N$

Bibromisatinic acid,.............$C_{16}\left\{\begin{matrix}H_4\\Br_2\end{matrix}\right. O_5\,N$

Isatin, and its substitution compounds, chlorisatin, bromisatin, bichlorisatin, and bibromisatin, form, with sulphites, salts composed of one equivalent of the base, one of the principles derived from indigo, and two atoms of sulphurous acid, having names and formulæ as under, the symbol MO representing the metallic oxide :—

Isatino-sulphites, ...$MO,\ C_{16}\,H_5\,O_4\,N,\ 2\,S\,O_2$

Chlorisatino-sulphites,....$MO, C_{16}\left\{\begin{matrix}H_4\\Cl\end{matrix}\right. O_4\,N,\ 2\,S\,O_2$

Bromisatino-sulphites,....$MO, C_{16}\left\{\begin{matrix}H_4\\Br\end{matrix}\right. O_4\,N,\ 2\,S\,O_2$

Bichlorisatino-sulphites,..$MO,\ C_{16}\left\{\begin{matrix}H_3\\Cl_2\end{matrix}\right. O_4\,N,\ 2\,S\,O_2$

Bibromisatino-sulphites,..$MO,\ C_{16}\left\{\begin{matrix}H_3\\Br_2\end{matrix}\right. O_4\,N,\ 2\,S\,O_2$

The long-continued action of dilute nitric acid upon indigo, occasions the formation of *indigotic*, sometimes termed *anilic acid*, and identical with *nitro-salicylic* or *nitro-spiroylic acid*. FOURCROY and VAUQUELIN, its discoverers, considered it to be benzoic acid. Its composition was subsequently ascertained by BUFF and by DUMAS. It was obtained by the action of nitric acid on spiroylic acid by MARCHAND, and GERHARDT procured it by the same process from salicin. It may be isolated by the following method :—Introduce into a tubulated retort, two parts of nitric acid having a specific gravity of 1·28, which has been previously diluted with an equal weight of water, and gradually add one part of coarsely-pounded indigo; adapt a receiver, and apply heat gently to the retort by means of a sand-bath; violent action will occur, and may require the removal of the heat from the apparatus. When quiescence has ensued, and the retort has cooled, resinous matter and crystals of indigotic acid will be found floating upon the surface of the menstruum. These must be separated and treated with water, which will dissolve the indigotic acid, the solution of which must be returned to the acid liquor in the retort, and the mixture so concentrated that crystallization will occur on cooling. The residue will deposit crystals of indigotic and nitropicric acid, which are to be redissolved in boiling water, the indigotic acid separating on cooling, while the nitropicric acid remains in solution.

The purification of indigotic acid from resinous and other impurities may be effected by dissolving the crystals—obtained by the process just described—in boiling water, and adding recently-prepared carbonate of lead to saturation; the liquor is then filtered as speedily as possible, and on cooling, *indigotate of lead* is deposited. This is dissolved in water in a state of ebullition, decomposed by dilute sulphuric acid, and the whole filtered while hot: on the filtrate being reduced in temperature, slender prisms of indigotic acid will form, yellow under the influence of adhering moisture, but nearly white when dry. If it is desirable to obtain the crystals perfectly colorless, it is merely requisite to employ dilute nitric instead of sulphuric acid, for decomposing the indigotate of lead.

The crystals formed in the aqueous solution of indigotic acid possess four equivalents of water. On desiccating them at a temperature between 300° and 450°, three atoms are expelled, and their formula is then $H\,O,\ C_{14}\,H_4\,O_5\,N\,O_4$, or $H\,O,\ C_{14}\,H_4\,O_9\,N$. Its composition in this state is represented underneath, that analysed by MARCHAND being obtained by the action of nitric upon salicylic acid; that employed in the examination of CAHOURS was procured from the oil of the *Gaultheria procumbens*, while the specimen of which DUMAS ascertained the relative constituents was derived from indigo.—

		Centesimally represented.			
	At. weight.	Theory.	Marchand.	Cahours.	Dumas.
14 Eqs. Carbon,.....	84 ..	45·90 ..	45·78 ..	45·55 ..	45·9
5 Eqs. Hydrogen, ..	5 ..	2·73 ..	2·76 ..	2·98 ..	3·0
10 Eqs. Oxygen, ...	80 ..	43·72 ..	43·77 ..	43·78 ..	43·3
1 Eq. Nitrogen,....	14 ..	7·65 ..	7·69 ..	7·69 ..	7·8
1 Eq. Indigotic acid,	183	100·00	100·00	100·00	100·0

When cautiously subjected to an elevated temperature, it volatilizes without decomposition, and condenses in white needles. Boiling water dissolves it in almost any proportion, but of the same menstruum at 50°, it requires for solution one thousand parts.

Its salts nearly all possess a yellowish hue and a nauseous taste, and, when heated, deflagrate. The acid gives with the salts of sesquioxide of iron a deep-red color; it has no influence on the protosalts, and does not cause a subsidence in gelatinous menstrua.

Nitropicric acid—mentioned above as being retained in solution in the preparation of indigotic acid—was, according to BRANDE, first noticed in the year 1788 by HAUSMAN. It was subsequently obtained by the action of nitric acid upon silk by WELTER, and bore, for a protracted period, the appellation of *Welter's bitter principle;* its acid properties were first described by CHEVREUL; the next examination was performed by LIEBIG, and DUMAS has since completed a more exact investigation of it.

LIEBIG prepares the acid in the following manner :—A portion of the best indigo, broken into small fragments, is gently heated with eight or ten times its weight of nitric acid of moderate strength. Solution occurs, an abundance of nitrous vapor is evolved, and the mass swells. After the scum has fallen, the liquid is boiled, and nitric acid added as long as any disengagement of red fumes is occasioned. When the liquid has become cold, semi-transparent yellow crystals form in large quantity, and, if the operation has been well conducted, no artificial tannin or resin is present. The crystals are edulcorated with cold water, and then boiled in water sufficient to dissolve them. If any globules of tannin form on the surface of the menstruum, they must be carefully removed by touching them with bibulous paper. Then, filtering the fluid and allowing it to cool, yellow brilliant crystalline plates will be obtained, which will not lose their lustre by washing. To procure the substance perfectly pure, the crystals must be redissolved in boiling water, and neutralized by carbonate of potassa. Upon cooling, the potassa salt crystallizes, and should be purified by repeated crystallizations. On mixing the first mother-liquor with water, a considerable brown precipitate is obtained, which, being dissolved in boiling water, and neutralized by carbonate of potassa, also affords a quantity of the alkaline compound. All the potassa salt obtained in these operations is redissolved in boiling water, and nitric or hydrochloric acid added; as the solution cools, the nitropicric acid will be observed to form very brilliant plates of a clear yellow color, generally in equilateral triangular forms. Sometimes crystals are not formed after the action of nitric acid on the indigo, in which case the liquor must be evaporated and water added, when the acid will precipitate, and purification may be effected as already recited. Four parts of indigo yield one of this acid.

When nitropicric acid is subjected to heat, it liquefies, and is volatilized without decomposition; when suddenly exposed to a strong heat, it inflames without explosion, its vapors burning with a yellow flame, and a carbonaceous residue remaining. It is only slightly soluble in cold, but much more in boiling water. The aqueous menstruum has a bright-yellow color, and an extremely bitter taste, reddens litmus, and acts like a strong acid on metallic oxides, dissolving them and giving rise to peculiar crystalline salts. Ether and alcohol dissolve it readily. When fused in chlorine or with iodine, it is not decomposed, nor does chlorine water affect it. Cold sulphuric acid leaves it intact; when hot, it dissolves it, but water separates it again without alteration. Boiling hydrochloric acid does not affect it, and nitrohydrochloric acid only with great difficulty.

Most chemical authors, says **BLUMENAU**, state that nitropicric acid is not decomposed by nitric acid; but this is an error, and under certain conditions it is resolved into nitric oxide, oxalic acid, and perhaps also carbonic acid. In the experiments performed by him to ascertain this point, the nitropicric acid was prepared by placing three pounds of the best indigo in thirty-five pounds of nitric acid just at the point of ebullition; as the violent action subsided, the whole was removed into a retort. A considerable quantity of the—so called—resin had formed, but the liquid, on cooling, furnished abundance of crystals. In order to destroy the resin, the contents of the retort were for seven days kept simmering ten hours *per diem.* Red vapors were constantly evolved, all but a mere trace of the resin had disappeared, and the inspissated liquids now furnished very few crystals of nitropicric acid; instead of weighing twelve ounces, they were only twelve drachms. The whole operation was most strictly watched and carefully conducted. The author, therefore, was compelled to attribute the loss of nitropicric acid to its decomposition by the nitric acid. In a later investigation, when heat was applied only for a very short time, the produce always amounted to one-fourth of the indigo employed, thus proving that a decomposition of the nitropicric acid must have occurred in the former operation. According to the last-mentioned chemist, the form of the crystals of nitropicric acid is very variable. Those obtained from boiling water were of a lemon or canary color, laminated and opaque, but by exposure to warm air becoming transparent and of a yellowish-brown tinge. The crystallized acid obtained from alcohol had the same form, transparency, and hue. From ether the acid crystallized on slow evaporation in beautiful yellowish-brown transparent crystals, having a faint glassy lustre, and in the form described by **MITSCHERLICH**: after long exposure to the air these had the color of the thin laminæ which were obtained from hot water; by subjecting them to the action of the atmosphere, they were again rendered transparent.

The formula usually assigned to nitropicric acid is,

$$HO,\ C_{12} \left\{ \begin{matrix} H_2 \\ 3\ NO_4 \end{matrix} \right. O.$$

It has been analysed with the following results:—

		Centesimally represented.				
	At. weight.	Theory	Marchand.	Schunck.	Dumas.	Laurent.
12 Eqs. Carbon,....	72	31·45	31·43	31·97	31·8	31·86
3 Eqs. Hydrogen,...	3	1·31	1·36	1·36	1·4	1·52
14 Eqs. Oxygen,....	112	48·91	48·72	48·16	48·3	48·00
3 Eqs. Nitrogen,...	42	18·33	18·49	18·51	18·5	18·62
1 Eq. Crystallized Nitropicric acid,	229	100·00	100·00	100·00	100·0	100·00

All the salts of nitropicric acid readily crystallize, and, when subjected to heat, explode with more or less violence. When they are placed in contact with lime and sulphate of iron, blood-red solutions are formed, containing a new acid in combination with lime.

Another very extensive series of entirely distinct compounds originates from the action of the alkalies upon indigo. A concentrated boiling solution of caustic potassa, having a specific gravity of 1·45, dissolves indigo rapidly, and the menstruum assumes a brown color; on evaporation, brilliant crystals begin to appear, and, when cool, a concrete mass remains, which affords with water a brown, and with alcohol a deep-green solution. The former is similar to the alkaline solution of indigo-white, noticed at page 593, and very quickly becomes coated with a beautiful iridescent and partly crystalline scum of indigo-blue. On nearly neutralizing the potassa by a mineral acid, a blue-green precipitate is formed, and a golden-yellow liquor is obtained on filtration, which, on being supersaturated with acetic acid, gives a voluminous brown flocculent deposit, containing, according to **FRITZSCHE**, a new body, termed by him *chrysanilic acid.* To separate it, the subsidence is agitated with its bulk of ether; a golden-yellow menstruum results, which, when evaporated, leaves the acid as a reddish-yellow substance. When thrown down from its alkaline solution by an acid, and exsiccated, it has the color of kermes. Its solution in the alkalies is yellow, and on adding an excess of the solvent a green tinge appears, and it becomes covered with a pellicle of the same hue, which, under the microscope, seems to be somewhat crystalline. When subjected to ebullition in the dilute mineral acids, it affords a red liquid, which, on cooling, deposits bluish-black acicular crystals, and *anthranilic acid* remains dissolved in the menstruum. The composition of chrysanilic acid is extremely uncertain. **FRITZSCHE** has, however, assigned to it the formula $HO, C_{28}H_{10}O_5N_2$.

To prepare anthranilic acid, indigo-blue is kept boiling in a solution of caustic potassa—specific gravity 1·35—a little water being occasionally added as the liquor acquires a thicker consistence. Previous to the disappearance of the last remains of the indigo, finely pulverised binoxide of manganese is added to the boiling menstruum, till a sample of it, on dilution with water, no longer deposits indigo-blue; if it then be heated with an excess of acid, it only yields a slight brown precipitate, and retains in solution *anthranilate of potassa*, and a considerable amount of caustic alkali. In this state it is to be diluted with water in a state of ebullition, supersaturated by dilute sulphuric acid, and filtered. The filtrate is then neutralized with potassa, and evaporated to dryness. The residue consists of sulphate and anthranilate of the alkali, and a brown coloring matter; the latter two are abstracted by hot alcohol, which leaves the sulphate of potassa. On distilling off the spirit, dissolving the remainder in water, and supersaturating by acetic acid, orange-colored crystals of impure anthranilic acid are deposited; these are now combined with lime, the resulting anthranilate of that earth dissolved in hot water, and the solution decomposed by acetic acid: on cooling, the hydrated anthranilic acid forms transparent yellow foliated crystals, terminating dihedrally. A saturated solution of the salt of lime, decomposed by acetic acid, deposits acicular crystals of anthranilic acid, which are white, and possess a very bitter taste.

According to LIEBIG, anthranilic acid dissolves sparingly in cold water, but is readily soluble in alcohol and ether, and these solutions have the taste of benzoic acid, and give an acid reaction. It has been analysed with the following results:—

		Centesimally represented.		
	At. weight	Theory.	Fritsche.	Liebig.
14 Eqs. Carbon,..................	84	61·31	61·82	62·13
7 Eqs. Hydrogen,..................	7	5·11	5·09	5·16
4 Eqs. Oxygen,..................	32	23·36	22·25	32·71
1 Eq. Nitrogen,..................	14	10·22	10·84	
1 Eq. Crystallized anthranilic acid,	137	100·00	100·00	100·00

In the year 1841, a communication was made to the Academy of Sciences at Paris, from which it appeared that GERHARDT, on treating indigo with hydrate of potassa, produced valerianic acid. The prescribed method was as follows:—

Indigo, cut into small pieces, is to be placed in fused hydrate of potassa, in which it dissolves, becoming yellow, and largely disengaging ammonia and hydrogen. On fusion, a mixture of valerianate and carbonate of potassa is obtained, from which, by distilling it with dilute sulphuric acid, valerianic acid is separated. GERHARDT expressed the transformation in the following equation:—

$$\underbrace{C_{16}H_5O_2N}_{\text{Indigo.}} + \underbrace{14\,HO}_{\text{Water.}} = \underbrace{HO, C_{10}H_9O_3}_{\text{Hydrated valerianic acid.}} + \underbrace{6\,CO_2}_{\text{Carbonic acid}} +$$
$$\underbrace{NH_3}_{\text{Gaseous ammonia}} + \underbrace{6\,H}_{\text{Hydrogen.}}$$

The carbon of the indigo is thus divided, and forming partly valerianic, and partly carbonic acid, it combines with the potassa. The carbonic acid is formed at the expense of the water, three equivalents of the hydrogen of which, uniting with the nitrogen, produce gaseous ammonia, while the remainder of the same gas escapes in the reaction. This transformation, however, which in the above equation seems so easily developed, did not proceed with the same facility, under other hands, in the crucible; WINKLER and ERDMANN alike repeated the experiments of GERHARDT, but unsuccessfully.

To bring this matter to a decision, the Editor repeated the process, and made a full examination of the acid thus formed.

The attentive consideration of the action of potassa on indigo, causes, *from theoretical reasons alone*, the formation of valerianic acid to appear in the highest degree problematical.

In the Editor's investigation, the action of potassa on pure indigo was first studied. Indigo-blue was heated in a silver capsule with hydrate of potassa, until a portion, on treatment with water and acids, gave evidence that the whole of the coloring matter was decomposed. A trifling excess of sulphuric acid was now added, which caused a vivid effervescence, and the evolution of a peculiar odor. The whole being filtered, and the filtrate distilled, a clear liquid, possessing the same singular smell, and giving an acid reaction, was obtained, and from which a baryta compound was formed. This afforded indubitable proofs of the presence of acetic acid.

A larger quantity of indigo was now treated in the same manner, but the baryta compound was also distilled with concentrated phosphoric acid. The distillate gave an intense acid reaction, and possessed the odor of acetic acid. The analysis of the baryta and silver salts, the evolution of acetic ether on the ebullition of the baryta compound with alcohol and strong sulphuric acid, as well as the respective reactions with arsenious acid, nitrate of mercury and other tests, gave infallible evidence that the so-called valerianic acid was acetic acid, and that only.

The acetic acid seems to be formed from foreign substances which are accidentally mixed with the indigo-blue. Reduced indigo—which was not, however, absolutely pure—gave a much smaller amount of the acid than the indigo of commerce. The valerianic acid obtained by GERHARDT—if it was obtained, and the statement, from such an eminent chemist, scarcely admits of doubt—must have been derived from foreign matter present in the indigo he employed.

When anthranilic acid is mixed with pulverised glass, and heated rapidly, it is resolved into carbonic acid and *anilin*, a powerful base, devoid of oxygen.

$$\underbrace{C_{14}H_7O_4N}_{\text{Anthranilic acid.}} = \underbrace{2\,CO_2}_{\text{Carbonic acid.}} + \underbrace{C_{12}H_7N.}_{\text{Anilin.}}$$

It was formerly denominated *crystallin*, from its great tendency to form crystallizable salts with acids, and when obtained from coal tar, it is frequently termed *cyanol* or *kyanol*. It seems first to have been noticed by UNVERDORBEN, in the empyreumatic oil obtained when distilling bone and other animal substances. RUNGE then obtained it as one of the products of the distillation of coal tar. It was procured on the distillation of anthranilic acid by FRITZSCHE, and ZININ produced it by the action of sulphide of hydrogen upon *nitrobenzid.* He termed it *benzidam*, representing it as an *amide of benzin*, $C_{12}\ H_5 + N\ H_2$; this appellation was subsequently changed to *benzidin*, but Dr. A. W. HOFMANN has more recently proved it to be identical with anilin, shown cases of its formation from other bodies, and added much to the knowledge of its properties, as well as those of its compounds. As has been mentioned above, anilin may be obtained by heating anthranilic acid with powdered glass, but it is more advantageously procured by the dry distillation of an alkaline salt of anthranilic acid, or indigo may be added to a hot solution of caustic potassa, and the resulting compound at once distilled. The product from either of these methods of manipulation is impure, but all the foreign matters may be removed by distilling it off potassa in an atmosphere of carbonic acid.

But HOFMANN has shown that the most eligible mode of isolating it is to heat isatin with hydrate of potassa, carbonate of the alkali being also formed, and hydrogen evolved.

$$\underbrace{C_{16}\ H_5\ O_4\ N}_{\text{Isatin}} + \underbrace{4\ (KO,\ HO)}_{\text{Hydrate of potassa.}} = \underbrace{C_{12}\ H_7\ N}_{\text{Anilin.}} +$$
$$\underbrace{4\ (KO,\ CO_2)}_{\text{Carbonate of potassa.}} + \underbrace{H_2}_{\text{Hydrogen.}}$$

Anilin is a colorless, oily liquid, of very high refractive and dispersive power, having a potent disagreeable odor, and a hot aromatic flavor. According to HOFMANN, its boiling point is 360°, but it is extremely volatile at ordinary temperatures, and the greasy mark which it occasions on paper speedily vanishes. Its specific gravity at 60° is 1·020. Cold water dissolves it to a certain extent, and the solution becomes turbid when subjected to heat. Alcohol, ether, and fat and volatile oils dissolve it in all proportions. With turmeric or reddened litmus paper, it affords no alkaline reaction, but it causes the violet hue of dahlia paper to turn green. White fumes appear when a glass rod, moistened with hydrochloric acid, is held over its aqueous solution. When aided by heat, anilin dissolves sulphur, but on cooling it is deposited in prismatic crystals: it also takes up phosphorus and camphor, but not copal or caoutchouc.

The following is its composition, FRITZSCHE's analysis being performed on anilin procured from anthranilic acid; ZININ arrived at his results from the examination of *benzidin*—the product of the action of sulphide of hydrogen upon nitro-benzid—while the researches of HOFMANN were conducted upon *cyanol*, or anilin obtained by the distillation of coal tar:—

		Centesimally represented.			
	At. weight.	Theory.	Fritzsche.	Zinin.	Hofmann.
12 Eqs. Carbon,.....	72 ..	77·42 ..	78·05 ..	77·23 ..	77·307
7 Eqs. Hydrogen,..	7 ..	7·53 ..	7·60 ..	7·50 ..	7·720
1 Eq. Nitrogen,....	14 ..	15·05 ..	14·98 ..	14·84 ..	14·973
1 Eq. Anilin,......	93	100·00			100·000

Anilin neutralizes acids, forming salts which crystallize with remarkable facility, and which, on exposure to the atmosphere, absorb oxygen, acquiring a rose color, gradually passing into brown.

Anilin is readily recognised by its forming with chloroxide of calcium—bleaching powder—a compound of a beautiful but fugitive violet-blue color, which is generally regarded as a product of oxidation, but, according to FRITZSCHE, containing chlorine. Its composition has not yet been ascertained.

The addition of a few drops of nitric acid to anhydrous anilin gives rise to a fine blue color, which, on the application of a slight heat, passes into yellow, and a violent action results, sometimes followed by explosion; or, on the other hand, various changes of color are produced, and crystals of nitropicric acid are ultimately formed. On adding anilin to a solution of permanganate of potassa, binoxide of manganese is separated, and oxalic acid and ammonia are produced.

Various compounds are occasioned by the action of chlorine, bromine, nitric acid, cyanic acid, sulphide of carbon, and other substances, upon anilin, which, in a scientific point of view, are highly interesting, but are too numerous and complicated to warrant description. Many of those already noticed seem very unlikely to be of service in dyeing, and yet the same opinion was formerly held respecting the yellow salts produced by the combination of chromic acid with lead, while the advantage taken of this fact has completely revolutionized the tinctorial art.

KERMES.—*Kermes grains*, *alkermes*, are the dried bodies of the female insects of the species *Coccus ilicis*, which feed upon the leaves of the prickly oak—*Quercus ilex.* The word kermes is Arabic, and signifies little worm; in the middle ages this dye-stuff was, therefore, called *Vermiculus* in Latin, and *Vermillion* in French. It is curious to consider how the latter name has been since transferred to red sulphide of mercury.

Kermes has been known in the East since the days of MOSES; it has been employed from time immemorial in India to dye silk; and was used also by the Greek and Roman dyers. PLINY designates it *Coccigranum*, and says that there grew upon the oak in Africa, Sicily, *et cetera*, a small excrescence like a bud, termed *Cusculium;* that the Spaniards paid with these grains half of their tribute to the Romans; that those produced in Sicily were the worst, those from the neighbourhood of Emerita in Lusitania the best, and that they were employed for dyeing purple.

In Germany, during the ninth, twelfth, thirteenth, and fourteenth centuries, the rural serfs were bound to deliver annually to the convents a certain quantity of kermes—the *Coccus polonicus*—among the other products of husbandry. It was collected from the trees upon Saint John's day, between eleven o'clock and noon, with religious ceremonies, and was therefore called *Johannisblut*—Saint John's blood—as also German cochineal. At the above period, a great deal of the German kermes was consumed in Venice for dyeing the scarlet to which that city gives its name. After the discovery of America, cochineal began to supersede kermes for all brilliant red colors.

The principal varieties of kermes are the *Coccus quercus*, the *C. polonicus*, the *C. fragariæ*, and the *C. uva ursi.*

The *Coccus quercus* insect lives in the South of Europe upon the kermes oak. The female has no wings, is of the size of a small pea, of a brownish-red color, and is covered with a whitish dust.

The kermes of Poland, or *Coccus polonicus*, is found upon the roots of the annual and perennial *scleranthus*, in sandy soils of that country, and the Ukraine, and has the same properties as the preceding.

Coccus fragariæ is found principally in Siberia upon the root of the common strawberry.

The *Coccus uva ursi* occurs in Russia, is twice the size of the Polish kermes, and dyes with alum a fine red.

When good, kermes is plump, of a deep-red color, having an agreeable smell, and a rough and pungent taste. Its tinctorial matter is soluble in water and alcohol; it becomes yellowish or brownish with acids, and violet or crimson with alkalies. Sulphate of iron blackens it. With alum it dyes a blood-red; with sulphate of iron, an agate-grey; with sulphate of copper and tartar, an olive-green; with tartar and a salt of tin, cinnamon-yellow. Scarlet and crimson dyed with kermes were called *grain colors*, which are accounted more durable than those of cochineal. The latter, however, and lac-dye, have now nearly superseded the application of kermes as a tinctorial substance in England.—*Ure.*

For a red, with tin, about twelve times the quantity of kermes as of cochineal is required, and the color is rather inferior. As a dye it is not much used, and only for silk or woollen. There seems to be no affinity between cotton and the tinctorial matters of *cochineal, lac*, and *kermes.*

Lac—*Laque*, French; *lack*, German—is a resinoid substance, the secretion of which appears to depend upon the puncture of a small insect—*Coccus ficus*—made for the purpose of depositing its ova upon the branches of several plants, especially the *Ficus religiosa* and *indica*, the *Rhamnus jujuba*, the *Croton lacciferum*, and the *Butea frondosa*, which grows in Assam, Siam, Pegu, Bengal, and Malabar. The twig soon becomes encrusted with a mammelated substance of a red color, more or less deep, nearly transparent, hard, and having a brilliant conchoidal fracture. The stick-lac of Siam is best, that of Assam ranks next, and, last, that of Bengal, in which the resinous coat is thin, scanty, and irregular According to the analysis of Dr. John, stick-lac consists, in one hundred and twenty parts, of—

An odorous common resin,	79·00
A resin insoluble in ether,	20·00
Coloring matter, analogous to that of cochineal,	4·50
Bitter balsamic matter,	3·00
Dun yellow extract,	0·50
Acid of the stick-lac—laccic acid,	0·75
Fatty matter, like wax,	3·00
Skins of the insects, and coloring matter,	2·50
Salts,	1·25
Earths,	0·75
Loss,	4·75
	120·00

According to Franke, the constituents of stick-lac are—resin, 65·7; substance of the lac, 28·3; coloring matter, 0·6. Unverdorben distinguishes no less than five distinct resins, together with coloring and fatty matter, and a resinoid, to which John gave the name of *laccin.* Hatchett's results are as follow:—

	Centesimally.
Resin,	68·0
Coloring matter,	10·0
Wax,	6·0
Gluten,	5.5
Foreign bodies,	6·5
Loss,	4·0
	100·0

When the resinous concretion is taken off the twigs, coarsely pounded, and triturated with water, the greater part of the tinctorial matter is dissolved, and the remaining granular portion dried in the sun, constitutes *seed-lac.* It contains less coloring matter than the stick-lac, and is much less soluble. Hatchett found in it—

	Centesimally.
Resin,	88·5
Coloring matter,	2·5
Wax,	4·5
Gluten,	2 0
Loss,	2·5
	100·0

Shell-lac is made in India by putting the seed-lac into an oblong bag of cotton-cloth, which is held over a charcoal fire till the contents begin to melt, when the bag is twisted so as to strain the liquefied resin through its interstices, whence it is allowed to drop upon smooth stems of the banyan tree. In this way the resin spreads into thin plates, in which state it is found in commerce. The Pegu stick-lac, being very dark colored, furnishes a shell-lac of a corresponding deep hue, and therefore of inferior value. A stick-lac of an intermediate kind comes from the Mysore country, which yields a brilliant lac-dye, and a good shell-lac. Hatchett analysed shell-lac, and found—

	Centesimally.
Resin,	90·9
Coloring matter,	0·5
Wax,	4·0
Gluten,	2·8
Loss,	1·8
	100·0

The tinctorial principle of lac is prepared in India by evaporating its aqueous infusion to dryness, and forming the residue into cakes of about two inches square, and half an inch in thickness. It is imported in two forms, called *lac-lake* and *lac-dye*, which contain about fifty per cent. of coloring matter, combined with more or less resin, and with earthy matters, consisting chiefly of carbonate and sulphate of lime, and silicic acid. According to Dr. Ure, the cakes of *lac-dye* imported from India, impressed with peculiar marks to denote their various manufacturers, are now exclusively employed in England for dyeing scarlet cloth, and are found to give an equally bright color, and are not so much affected by perspiration, as that produced by cochineal. The solvent of the lac-dye is dilute sulphuric or hydrochloric acid; more particularly the latter, and the correct mordant is chloride of tin and tartar. The general characteristics of the coloring matter of lac seem very similar to those of cochineal and kermes, but it has not been the subject of any specific examination.

An excellent red is produced upon one pound weight of woollen by boiling for half an hour in water, to which has been added two ounces of lac, two of tartar, and four ounces by measure of *lac spirit*—perchloride of tin.

LOGWOOD.—*Bois de Campeche*, *Bois bleu*, French; *Blauholz*, German; *Hæmatoxylum*, Latin.—This wood is obtained in great abundance in Jamaica and on the eastern shores of the Bay of Campeachy, and is imported into this country in small pieces or blocks. The wood from the two localities produces different qualities of dye; on this account the name of its habitat is affixed to each, and the two kinds are distinguished in commerce as Campeachy and Jamaica logwood. The former is superior to the latter, and consequently fetches a higher price in the market. The logwood tree is called by botanists *Hæmatoxylum Campechianum.* In a favourable position it grows to a very large size. The bark of the tree is smooth and thin, and furnished with thorns, its leaves resembling those of the common laurel. The wood is very hard and close in the fibre, and is capable of taking on a fine polish, it is somewhat heavier than water, and consequently sinks when put into that liquid.

Logwood was introduced into this country as a dye early in the sixteenth century, and was in all probability first used by the dyers in these days, as it is still in some cases, to serve as an auxiliary in dyeing blues and blacks upon woollen, not only making the color more fugitive than had been previously the case with the use of woad, but seriously affecting the interests of the cultivators of the woad plant. These were, doubtless, the reasons of the absurd act passed by the government in the reign of Elizabeth, forbidding entirely the use of logwood under pains and penalties, as stated in the historical portion of this article—an act affording a striking proof of the gross impropriety of legislative interference with popular industry. This enactment had the natural effect of retarding the full development of the valuable dyeing properties of the wood. Nevertheless, they became gradually known; and when those interested in opposing the use of logwood found a much more serious intrusion upon their interests by the introduction of indigo, the restriction upon logwood was gradually relaxed, and then the virtues of this most useful dyewood began to be generally acknowledged. This was the natural result of experience, and perhaps there is no dye now so universally employed and so generally useful.

In the beginning of this century, the chemical properties of this tinctorial agent began to be studied by two French chemists, CHEVREUL and ERDMANN. The former, in a memoir published in 1811, furnished a process for separating the coloring matter, which he considers a distinct compound existing in the wood, and termed it *hæmatin*, a name which has since given place to *hæmatoxylin*, to avoid confounding it with a substance existing in the blood of animals, and which has been long known under the former designation. Besides this coloring matter, logwood also contains a fatty or resinous substance, volatile oil, a brown ingredient containing tannin, acetic acid, woody fibre, various salts, consisting generally of the phosphate, sulphate, and acetate of lime, acetate of potassa, and chloride of potassium; and sometimes the oxides of aluminium, silicium, manganese, and iron. These ingredients, however, vary, some woods having more than others, and others wanting some of them altogether; the differences of constitution being occasioned by the qualities of the soil on which the wood is matured.

According to NAPIER, the average ash left after incinerating several samples was 1·5 per cent., half of which was lime, with a trace of iron, the remainder consisting of magnesia, alumina, and silica.

The decoction of logwood, when newly made, is of a deep red, which is rendered paler but brighter colored by acids; alkaline substances give it a purplish or violet-blue hue; acetate of lead causes a slate-blue, alum a violet precipitate. The salts of iron make it dark violet-blue. When the infusion is exposed to the atmosphere it absorbs oxygen, becomes pale in color, and then acquires the property of precipitating gelatin, which it had not before.

CHEVREUL'S process for procuring hæmatoxylin is to subject ground logwood to digestion for a few hours in water at 120° or 130°, afterwards filtering the liquor and evaporating to dryness; the residue is digested in strong alcohol for a day; this is again filtered, and the clear liquor boiled down till it becomes thick; to this is added a little water, and it is evaporated anew; it is then set aside, and the coloring matter crystallizes.

It is best obtained, says ERDMANN, by pulverizing the watery extract of the wood as prepared for pharmaceutical use, mixing it with a portion of sand to prevent agglutination, and digesting the mixture with six or eight times its volume of ether; it should be frequently shaken and poured off, and the greater part of the ether distilled from it; the residue is then mixed with water, and left to spontaneous evaporation in a lightly-covered basin. After some days the hæmatoxylin crystallizes, and may be washed with cold water, and pressed between folds of bibulous paper to free it from the mother-liquor. From two pounds of extract digested in two pounds of ether, this chemist obtained four ounces of hæmatoxylin.

Hæmatoxylin occurs in transparent brownish-yellow prismatic crystals, which afford a pale-yellow powder; they are efflorescent, and in a dry atmosphere lose the greater part of their water of crystallization. When rapidly heated to 212° they fuse, and then gradually become anhydrous. Hæmatoxylin has a sweet taste resembling that of liquorice root, without either bitterness or astringency; with alcohol and ether it produces reddish-yellow solutions. It is very sparingly soluble in cold water, but that menstruum readily dissolves it when boiling, and on cooling deposits it in crystals, which ordinarily contain eight equivalents of water of crystallization; but if a concentrated hot solution be allowed to cool in a well-closed vessel, it forms pale-yellow granular crystals, which only include three atoms of water.

The composition of hæmatoxylin, in its anhydrous state, is represented by the formula $C_{40} H_{17} O_{15}$.

		Centesimally	
	At. weight.	Theory.	Erdmann.
40 Eqs. Carbon,...............	240	63·66	63·19
17 Eqs. Hydrogen,............	17	4·50	4·65
15 Eqs. Oxygen,..............	120	31·84	32·16
1 Eq. Anhydrous hæmatoxylin,	377	100·00	100·00

The ordinary crystals are $C_{40}H_{17}O_{15} + 8HO$, their ultimate elements being—

	At. weight.	Theory.	Erdmann.
40 Eqs. Carbon,.............	240	53·46	53·78
25 Eqs. Hydrogen,............	25	5·56	5·78
23 Eqs. Oxygen,.............	184	40·98	40·44
1 Eq. Crystallized hæmatoxylin,	449	100·00	100·00

When exposed to light, the crystals of hæmatoxylin gradually assume a reddish tint; their aqueous solution is reddened by nitric acid when very dilute, but if concentrated, effervescence is occasioned, and oxalic acid formed. Ammonia, either pure or carbonated, forms the most delicate test for hæmatoxylin, as under the influence of air it reddens the least trace of it. If air be carefully excluded, hæmatoxylin crystallizes unchanged from its ammoniacal solution, but when the atmosphere has access, the menstruum becomes purple: this, however, when acted on by sulphide of hydrogen, is bleached, and on evaporation yields colorless crystals of hæmatoxylin; but if it be continuously exposed, it gradually becomes opaque and of a deep cherry-red hue, and in this state acetic acid produces in it a bulky precipitate of the color of hydrated sesquioxide of iron. If the ammonia, as it volatilizes, be from time to time replaced, crystals are ultimately deposited of a compound of *hæmatéin* and ammonia. When hæmatoxylin is dissolved in a solution of potassa and carefully excluded from the atmosphere, no change occurs; but should air be admitted, oxygen is absorbed, and the color upon the sides of the vessel becomes first purple, and then brown. When baryta water is added to a solution of hæmatoxylin in water deprived of air, it causes a precipitate, white or pale-blue, quickly reverting to blue, red, and brown; carbonate of potassa produces the same effect, but less rapidly. The hydrated earths, and oxides of zinc, iron, copper, nickel, bismuth, and antimony, also precipitate hæmatoxylin, and the colors of these compounds, under the influence of air, are purple and blue. Chloride of barium gives a red, iron-alum a dark violet, and chloride of tin a rose-colored subsidence; alum occasions a red hue, with precipitation. When hydrated oxide of lead is introduced into a solution of hæmatoxylin, it becomes first blue, and then grey, in consequence of partial reduction. Acetate of lead yields a white deposit, soon substituted by blue. With salts of copper, the precipitates are at first greenish-grey, and then blue. Chlorides of mercury and platinum are not affected; that of gold is slowly, and nitrate of silver rapidly reduced.

Hæmatéin is formed by the action of air upon an ammoniacal solution of hæmatoxylin, as just noticed. It may be procured in a pure state by mixing three hundred to three hundred and fifty grains of hæmatoxylin with as much aqueous ammonia as is requisite for its solution, exposing the compound to atmospheric action, and occasionally adding a little fresh ammonia, so as to maintain it in very slight excess; in the course of a few days granular crystals are formed, which must be edulcorated with cold water, dried by pressure in bibulous paper, dissolved in water, and precipitated by acetic acid.

Hæmatéin, when thus purified, forms a reddish-brown precipitate, and, on exsiccation, reverts to a dark-green metallic hue; with hot water it forms a brown solution, which, when rapidly evaporated, affords a succession of greenish crystalline pellicles, and on cooling deposits the hæmatéin either in a granular or gelatinous form. The ultimate components of these crystals are—

		Centesimally.	
	At. weight.	Theory.	Erdmann.
40 Eqs. Carbon,.............	240	62·66	62·799
15 Eqs. Hydrogen,............	15	3·91	4·135
16 Eqs. Oxygen,.............	128	33·43	33·066
1 Eq. Crystallized hæmatéin,..	383	100·00	100·000

With nitric, hydrochloric, and dilute sulphuric acids, hæmatein forms red solutions. With ammonia a dark violet-colored granular powder is produced, which may be dried without loss of the base; its aqueous solution is deep purple, that in alcohol is brown, but becomes purple when water is added; by evaporating the aqueous solution in the air, it is decomposed. The elements of this compound of hæmatéin and ammonia, when dried over concentrated sulphuric acid *in vacuo*, were ascertained by ERDMANN to be $C_{40}H_{22}O_{17}N_2$. The same chemist has also described compounds of hæmatéin with oxide of lead and oxide of copper.

Logwood, as already mentioned, is very hard and close in the fibre. When used chipped in small pieces it requires long boiling to extract the coloring principle. To obviate this, the wood is now generally ground fine, by which means the operation is much facilitated. To avoid loss by dust in grinding, owing to the dryness of the wood, it is moistened by water, which greatly enhances the appearance of the wood, by producing a richer color upon it, and does not affect its dyeing properties; but from the fact, that a slight alkalinity given to the water heightens still more the color of the wood, and greatly facilitates the extraction of the coloring matter, some parties are in the habit of adding a little lime to the water sprinkled upon it, and thus impart to inferior wood the appearance of the good quality. All such practices are hurtful to its dyeing properties, and exercise a baneful effect upon the colors produced, particularly on light tints. All alkaline matters applied to logwood tend to make the colors dyed by it more fugitive, especially if the wood has been long in contact with such substances. Their presence may be detected by putting a little of the ground wood in a test tube, keeping it at summer heat in distilled water for some time, and then testing the solution with delicate test papers.

Although there is no direct chemical means known which may be readily practised by the dyer for testing the quality of the logwood he is about to purchase, nevertheless his own experience and practice, if rightly applied, will form a very good security against any gross fraud.

NAPIER has shown the average ash from logwood to be 1·5 per cent.; any admixture of sand may therefore be detected, by burning a small quantity and weighing the ash. The quantity of moisture may be ascertained by weighing 100 grains, spreading this upon a piece of paper or any flat vessel, keeping it exposed for several hours to a heat of boiling water, and then weighing again. After these preliminary trials, by taking different samples so dried, and dyeing a given weight of mordanted cotton with a given weight of each, an accurate comparative estimate is obtained; and if a known good sample is tested along with those on trial, the purchaser will have no occasion to complain that he had no means of ascertaining the value of the article sold to him. Of course, as certain qualities of logwood are known to be better adapted for certain tints or colors than others, the comparative trials should be made with cotton impregnated with different mordants; and as samples of logwood are often found to differ only in having less or more water in them, the moisture lost by drying will always have to be considered in comparing different qualities. The natural moisture in logwood is found to be from 12 to 16 per cent., differing, no doubt, according to its age and the locality in which it has been kept.

MADDER.—*Garance*, French; *Faberröthe*, German —is the root of the *Rubia tinctorum*, a plant of which two species are distinguished by LINNÆUS. It is common in the South of Europe, and in many parts of the Levant, and is largely cultivated in Holland; it attains to about three feet in height, and has a long spreading fibrous root, which is the part used in dyeing. The best roots are of the size of a writing quill, or, at most, of the little finger. They are semi-transparent, reddish, have a strong odor, a smooth bark, and should be of two or three years' growth. The root is taken from the ground, picked, and exsiccated, in order to be ground and preserved. In warm climates, it is dried in the open air; elsewhere, stoves are made use of. The stringy filaments and epidermis, termed *mulle*, as also the pith, are removed, leaving nothing but the ligneous fibres. Dr. URE gives the following as the method employed in the department of the Rhone for the preparation of madder:—

The roots are dried in a stove heated by a furnace, from which the air is allowed to issue only at the moment when it is judged to be saturated with humidity. Above the furnace flue, which occupies a great portion of the floor, are three gratings, on which the roots are arranged in layers of about eight inches. At the end of twenty-four hours, those on the first grated floor directly above the stove are dry, and are taken away and replaced by those of the higher floors. The desiccated roots are then thrashed with a flail, passed through fanners similar to those employed for corn, and shaken upon a coarse sieve. The finer particles are again winnowed and passed through a still finer sieve. These operations are repeated five times, using sieves successively finer and finer, and putting aside each time the portion which remains on the sieve. The matter which finally passes through is rejected as sand and dust. After these manipulations, the whole of the fibrous substances remaining are cleaned with common fanners, and all foreign matters, which had not been before removed, are now separated. The roots are then divided into different qualities, for which a brass sieve is used, the meshes of which are from one-fourth to one-eighth of an inch in diameter. The finest portion is rejected, while the coarsest is considered of the best quality. These roots, thus separated, are carried into a stove of a construction somewhat different from the first. They are spread out in layers of about four inches in thickness, on large lattice-work frames, and the drying is known to be complete when, on taking up a handful and squeezing, the roots break easily. On quitting the stove, the madder is placed, still hot, into a machine, where it is cut small, and the portion of the bark reduced to powder is separated. This operation is repeated three or four times, after which resort is had to the bolter. The madder which passes through the brass meshes of the bolter is considered as common, and that issuing from the extremity of the bolter is called the flour. Lastly, the madder, after being subjected to these processes, is ground in a mill with vertical stones, and afterwards passed through sieves of different degrees of fineness. The madder of Alsace is reduced to a very fine powder, and it requires a much longer boiling to extract its tinctorial matter than is necessary for the *lizari* of the Levant. The prepared madders ought to be carefully preserved from humidity, as they readily imbibe moisture, in which case fermentation injures their color. D'AMBOURNEY and BECKMANN have asserted, that it is more advantageous to employ the fresh root of madder than that which has been desiccated, especially by means of stoves. But in its state of freshness, its volume becomes troublesome in the dye-bath, and uniform observation seems to prove that it ameliorates by age. Besides, it must be rendered capable of keeping and carrying easily.

In commerce, the name of *lizari* has for a long time been restricted to the entire roots of the madder, while that of *madder* is applied to the pulverized roots.

Lizari is very little employed for the purposes of dyeing, and there is hardly any but that of Avignon which is met with in the markets of France: the lizari of Cyprus is of rare occurrence, while the Alsatian product is never met with.

The powders called madders are distinguished according to their origin, into Dutch, Alsatian, and madder of Avignon, or of the Comtat.

Before GIRARDIN wrote upon this subject, no work of materia medica, or of applied botany, had given the history of these powders, nor the peculiar characters of each variety. His situation, however, enabled him to make a particular study of this important tinctorial product; and the following remarks are the results of many and various observations:—

Dutch madder has a strong and nauseous odor; its taste is sweet, but with a mixture of bitterness; its color varying according to the marks, and passing from a brownish to an orange-red. The brownish-red tint, however, is applicable only to the *mulle* madder of each kind. The term *mulle*, or *bilon*, is applied to the inferior quality of madder, which consists of a mixture of the smallest roots, of the fibres and epidermis of the larger roots, of earthy matters, and of the refuse from the sieves.

In general, its powder is stringy, that is to say, its state of division is sufficiently large to exhibit the structure of the root. It is coarser than the other kinds of madder, which might be attributed to negligence, since frequently portions of lizari are met with which have never been submitted to the operation of grinding. This rough state of comminution, however, is no defect, since it prevents fraud. This powder seems greasy to the touch. Exposed to the action of the atmosphere it readily absorbs moisture, and when, for the sake of ascertaining its quality, it is exposed to humid air, its orange-red becomes bright, rich, and deep. This madder, to use a commercial term, *works* more than others; that is, it presents more decided modifications of color by exposure to moisture.

Dutch madder is either stripped or the contrary. In the first case, the roots have been freed from their epidermis, which gives greater brightness to the powder; in the second, they have been triturated without undergoing this operation, when the powder is of a more sombre hue. This madder cannot be used while fresh; it must at least be a year in the cask: after three years it is in full vigor.

The *pale* powder, or that of the first year, having a yellow aspect, soon undergoes fermentation; the divided particles then unite with each other, agglomerate, and increase in volume to such a degree that, after from one to two years, the dilation is so great, that the bottoms of the casks present a very marked convex form. The madder is then so hard, that, in order to take it out of the cask, a mallet or chisel must be used.

It keeps several years after having attained its greatest tinctorial power; but after about three years, the layers which line the sides of the casks then begin to lose their brightness; the madder assumes a pale-brown color, and enters into decomposition, the process of which is slow but certain; it subsequently becomes quite extinct, and the madder has a brown-red hue. When partially decomposed, it may still be used for brown grounds or light colors; but when age has affected all the tinctorial principles, it can only serve as *mulle.*

The marks current in the French markets are—

Mulle, O,
Superfine,
Not stripped or stripped, } or { Mulle.
Fine grappe.
Superfine grappe.

The term *grappe*, signifying bunch, is employed when age has given consistence to the powder, and designates its state of agglomeration.

Alsatian madder, which has replaced the Dutch in France, although it does not possess all its qualities, has the following characters:—

The smell is more penetrating than that of the preceding; taste, less sweet, but equally bitter; color varies from brown to bright-yellow, according to the mark; and the state of division is coarser. It easily absorbs moisture from the atmosphere by exposure, and changes from yellow to a dark-red.

As is the case with the Dutch madder, it is not employed while fresh; it is in the best condition when about two years old. It deteriorates sooner than the former, and it grows very hard in the casks, cohering to the very centre, there being the same difficulty to extract it. The progress of decomposition is similar, and the product which has undergone this process can only be used for dark tints.

Alsatian madder is never known by the denominations *stripped* or *not stripped*, although the epidermis is removed; the following marks alone distinguishing the varieties:—

O,	Mulle.
M F,	Mi fine.
F F,	Fine fine.
S F,	Superfine.
S F F,	Superfine fine.

The third quality, F F, is most generally used; S F F is nearly an exception to the method employed by the Alsatians in grinding, who are strict enough in their marks to be unwilling to prepare it very fine.

It is principally at Strasbourg, Hagenau, and Geisselbrunn, that the so-called Alsatian madder is manufactured.

Madder of Avignon is most generally used at the present time, and even preferred to the other kinds, because the dyer and the calico-printer find it easier to modify the reds according to wish. It is especially since the peace of 1815, that the use of this madder has increased.

Of all the kinds of madder, this sort has undergone the most modifications; indeed, it is almost the only kind in which variations are made in the marks and quality. In Holland, and in Alsatia, the quality specified is generally conformable to the mark. In Avignon, on the contrary, each manufacturer has a mark to designate its quality; and the mark S F F, which with one is beautiful, is but middling with another. The result is, that the trader cannot trust to the mark alone, which presents a different tint in each manufactory. The madder of Avignon, therefore, can only be bought after having been subjected to some comparative test.

The characters of this powder are—odor, agreeable, slightly penetrating; taste, sweetish bitter; color, either rose, bright-red, or brown-red, according to the roots employed in the preparation, and to the degree of mixture; state of division very fine; powder dry to the touch.

When submitted to the action of the atmosphere, it absorbs moisture less readily than the other species, but it does not work less, and subsequently affords a pale, or very dark-red, according to whether the powder operated on was *rosy* or *palus.*

In Avignon, the name *Palus* is given to some tracts of land anciently covered with marshes; these grounds, enriched by animal and vegetal remains, are eminently suited for the cultivation of madder; the roots they produce being almost all red, and of a superior quality; whilst other kinds of soils yield rose-colored roots.

The powder from the palus madder is of a dull and rather unsightly red, but on drying it becomes blood-red, and the shade may be varied at pleasure. A small quantity goes much further than a large amount of the rose-colored root.

The powder from the latter is of a bright-red, bordering a little upon yellow.

The madder, which is half palus, half rosy, is brilliant, well received in the market, and affords very satisfactory results in dyeing. The lustre of the rosy madder mingling with the rich depth of the palus, produces a most beautiful red.

In Avignon the terms *stripped* or *not stripped* are unknown. There the word *épuration* is used. A madder is purified from three, five, seven, or ten, and even as high as fifteen per cent. This mode of expression, however, is pure quackery, for how is a root to be purified except by depriving it of its epidermis; and how can it be imagined that the root may contain so much more or less of it, as to require that the purification should sometimes be carried to fifteen per cent.? One would have to suppose, that the weight of the epidermis was to that of the root as 1 : 7, 10, or 15, which is not the case.

The Avignon product may be used immediately on leaving the mills; but that which has been preserved in casks for a year is decidedly preferable. It keeps well, and undergoes little or no fermentation;—it does not cohere in a mass; after several years, however, it is decomposed with nearly the same symptoms as the other kinds: it is still used in this state. The small degree of eremacausis evinced, arises from its containing much less mucilaginous, saccharine, and bitter substances than the Dutch and Alsatian madder, for it is certain that the acid fermentation which is so energetically developed in the latter must be attributed to those substances.

Although pressed with great force into the casks, the madder retains much air between its particles, which, in time, acts upon the whole mass, giving it a uniform color, by oxidizing the primitive yellow principle, and changing it into a red. This theory, advanced by DECAISNE, very well explains why the madder powders are improved in quality by being preserved.

The exsiccation of the roots in the stove has great influence on the tint of the madder of Avignon. If dried at too high a temperature, the powder is dull, but does not, however, lose in quality.

At first, only two kinds of Avignon madder were known, the yellow and the red. The first has since disappeared, and the rosy is now substituted for it. It is difficult to give positive information as to the marks, especially since the manufacturers have appeared to agree in their attempts to confuse them, and thus to deceive buyers.

The following were the only marks originally known:—

Mulle.	
F F,	Fine fine.
S F,	Superfine.
S F F,	Superfine fine.

These brands were applied to the casks without any other designations. The tint alone decided to what sort of root the powder belonged. At present they are, as before indicated, either palus, rosy, or a combination in equal proportions of both these kinds.

The following are the marks:—

Mulle, FF, SFF, SFFF, EXTF, EXTSF, EXTSFF. The quality known as mulle has no additional distinction; to the signs for the other kinds, there are added, however, P for palus, P P pure palus, R P P pure red palus, or R, signifying rosy. According to these designations, the absurd mark of E X T S F R P P, to be understood as *extra superfine pure red palus*, is by no means a rarity.

It must be confessed, says GIRARDIN, that such absurdities can only exist in a country where fraud has made revolting progress. It often happens that the mark EXTSF, now used, is not equal to the old one of SFF.

The extra fine is especially manufactured from the heart of the ligneous portion of the root, and though less rich in tinctorial matter than the fleshy part or the bark, it affords a much more lively color.

The interior of the casks in which Avignon madder is packed, is generally lined with thick card-board, to prevent communication with the atmosphere, which blackens the powder, causes it to appear less beautiful, and, after a certain time, destroys much of its dyeing properties, which are also very quickly changed by light.

MM. BUCHOLZ, JOHN, and KUHLMANN gave the following as the constituents of the root:—

1. Red coloring matters.
2. Pale red, or fawn-colored matter.
3. Lignine.
4. Mucilaginous matters.
5. Gum and grape sugar.
6. Pectin and pectic acid.
7. Bitter and extractive principle.
8. An odorous resin.
9. Red resin.
10. Brown matter soluble in potassa.
11. Vegetal albuminous matters.
12. Various organic acids, partly combined with lime, viz., tartaric, malic, and pectic acids.
13. Mineral salts, carbonate, sulphate, and phosphate of potassa, chloride of potassium, carbonate and phosphate of lime, silica, phosphate of magnesia, and a remarkable quantity of tartrates of lime and potassa.

From these it will readily be perceived that the study of madder will involve a great many difficulties, and is an ample subject for investigation; and not a few of our eminent chemists, both in this and other countries, have engaged themselves in it.

The tinctorial principles of madder, notwithstanding numerous investigations, are as yet very imperfectly understood. BERZELIUS and RUNGE obtained and described five coloring matters—purple, red, orange, yellow, and brown.

Madder-purple may be procured in the following manner:—Boil the clean root repeatedly in a concentrated solution of alum, and filter whilst hot. On cooling, a brownish-red subsidence—consisting principally of *madder-red*—occurs, and must be removed by decantation. Next add sulphuric acid to the menstruum, which gradually throws down the purple. It may be purified by boiling in hydrochloric acid, digesting in alcohol; finally, distilling off most of the spirit, and allowing the residue to evaporate spontaneously.

Madder-red is abstracted from the aluminous deposit just mentioned, by boiling in dilute hydrochloric acid, and dissolving in alcohol. This is then boiled with a strong solution of alum, which causes the precipitation of the madder-red. It is purified by dissolving in ether, and the menstruum, on evaporating spontaneously, leaves it as a yellowish-brown crystalline powder.

Madder-orange requires a separate and distinct process. Clean madder roots are digested for about sixteen hours in eight parts of water, at a temperature of 60°. The infusion being filtered, gradually deposits minute crystals, which are collected, desiccated, and dissolved in boiling alcohol. The orange principle. which subsides on the cooling of the menstruum, is edulcorated in a filter with cold alcohol, till the filtrate is no longer tinged by sulphuric acid. This substance, when heated in a glass tube, exhibits similar reactions as madder-purple, except that the vapors are yellower; boiling solutions of alum form with madder-orange a yellow solution, depositing some of its color upon cooling.

Madder-yellow is very soluble in water, a property which characterises it from the other coloring principles; it has a gummy consistence, and forms no dye of any permanence; the better the quality of the madder, the less yellow it possesses. Dutch madder has generally a great quantity of madder-yellow.

Madder-brown.—This is a dark-brown substance, approaching to black, which is obtained during the preparation of the other coloring matters; it is neither soluble in alcohol nor water, and is of no known use as a dyeing agent.

The researches of MM. ROBIQUET and COLIN led them to the opinion, that only two important coloring principles exist in madder, which they termed *colorin* and *alizarin*, or *garancin;* the latter were first formed and described in 1828, but has since become a most important article in the dye-house, and will be considered more fully after giving some of the more recent chemical investigations into the nature of the compounds that exist in madder. Amongst the foremost in these investigations stands Dr. SCHUNCK. At the commencement of his researches, he says—RUNGE described five coloring matters which he obtained from madder, *madder-purple*, *madder-red*, *madder-orange*, *madder-yellow*, and *madder-brown*. This chemist states, as one result of his investigation, that he agrees with RUNGE in thinking that there is more than one coloring matter in madder, though he is of opinion that the substances which he enumerates and describes are not pure. Before, however, entering on this part of the subject, SCHUNCK first gives the results at which he arrived at in regard to alizarin. Alizarin is doubtless the most interesting and the most definite in its nature of all the substances contained in madder. It also presents itself the most easily to the observer, even on the most superficial examination. If madder be heated, spread out in a thin layer on a metal plate without carrying the heat far enough to char the woody parts of the root, its surface will be covered, in the course of a few hours, with small red or orange-colored crystals, which consist of alizarin. In the same way, any extract of madder, whether with water, alcohol, or alkalies, evaporated to dryness and gently heated, gives a crystalline sublimate of alizarin, which is variously colored from a light-yellow to a dark-red or brown. Now one of the first points to be ascertained in regard to this body was, whether it exists as such in the root, or whether it is formed by the process of sublimation. ROBIQUET, the discoverer, states that it pre-exists in the plant. He considered alizarin as the coloring principle of madder, and merely subjected it to sublimation for the purpose of purifying it. But his investigation presents us with no convincing proof of this opinion, for the extract of madder with water, alcohol, *et cetera*, from which he prepares his alizarin by sublimation, shows no trace of anything crystalline; and many chemists have asserted, in consequence, that it is a product of decomposition, being formed by the action of heat in the same way as pyrogallic, pyrotartaric acid, and many other bodies. SCHUNCK affirms, however, that it exists in the plant as such, having in more than one way obtained it in a crystallized state without the intervention of heat. If an extract of madder be made with cold water, a brown fluid is obtained, which produces no reaction on test paper. After being exposed, however, to the action of the atmosphere for some hours, it acquires a distinctly acid reaction; and if it be now examined carefully, there will be found floating about it a number of long hair-like shining crystals: these crystals are alizarin.

Dr. SCHUNCK afterwards found that this substance, here named alizarin, had in it two coloring principles; to the one he gave the name of *rubiacin*, the other being true alizarin.

He then says—it is necessary to state that the substance called alizarin, in the paper read on this subject, at the Southampton meeting of the British Association, is now termed rubiacin; and he is of opinion that the substance discovered by ROBIQUET, and called by him alizarin, does not agree in its properties with rubiacin; but after carefully comparing his account with the results obtained by himself, he has come to the conclusion that the substance to which he applied the name of alizarin is identical with that of ROBIQUET.

Alizarin has the following properties:—When heated on platinum foil, it melts and burns with a bright flame. When heated in a glass tube closed at one end, it melts and gives yellow fumes, which condense on the colder parts of the glass, forming an oil, which soon congeals to a mass of orange-colored crystals possessing a considerable lustre, which are unchanged alizarin. A carbonaceous residue is usually left in this case, but SCHUNCK has no doubt that, by carefully heating, it might be entirely volatilized. Alizarin is slightly soluble in boiling water. The solution has a yellow color, but so small is the quantity dissolved, that the alkali or earth usually contained in filtering paper is sufficient to render the solution pink, on being filtered to separate it from the excess of alizarin. Hence, no doubt, arises the statement found in books, that alizarin dissolves in water with a pink color. The boiling solution deposits it on cooling in yellow crystalline flocks. It is soluble in boiling alcohol. The solution has a deep yellow color, and deposits nothing on cooling; but, on evaporation, the alizarin is left in long needle-shaped or prismatic orange-colored crystals possessing a considerable lustre. The color of the crystals very much resembles that of bichromate of potassa. Concentrated sulphuric acid dissolves alizarin in the cold with a blood-red color. It is precipitated from this solution by water in flocks of a dull orange color. Dilute nitric acid decomposes it on boiling with an evolution of nitrous acid. If it is still mixed with fat, then the fat remains behind after the alizarin has been decomposed and dissolved by the nitric acid. It is not affected by hydrochloric or acetic acid. On passing chlorine into water in which alizarin is suspended, the color of the latter is changed to yellow, but it is seemingly not destroyed. It is decomposed by bichromate of potassa and sulphuric acid. A boiling solution of sesquichloride or nitrate of iron decomposes it with a copious evolution of gas, a pungent smell resembling that of aldehyd being at the same time given off. The product of this decomposition will presently be described. Chloride of gold is not reduced by it on boiling; but, on the addition of caustic potassa, metallic gold is deposited in shining scales. It is soluble in caustic and carbonated alkalies with a splendid purple color, and is reprecipitated by acids in flocks of a dull orange color. The solution in ammonia gives with the chlorides of barium and calcium precipitates of a splendid purple color; with sugar of lead, a light purple precipitate. The compound with alumina produced by introducing hydrate of alumina into an alcoholic solution of alizarin, is not decomposed by a concentrated solution of caustic potassa. The alcoholic solution gives with acetate of iron a dark purple precipitate; with acetate of copper, a light purple precipitate; with protochloride of tin no precipitate, except on the addition of ammonia, when a light red precipitate is produced. If alizarin and a piece of mordanted cloth be introduced into boiling water, and the boiling be continued for some time, the cloth becomes slowly dyed, and the mordants assume the tints peculiar to the so-called madder colors. The alizarin slowly disappears in the same measure as the cloth becomes dyed, even though less water had been taken than was sufficient to dissolve the whole quantity. It is evident, therefore, that, in the process of dyeing, the alizarin, which is dissolved in the first instance by the boiling water, is taken up by the mordants of the cloth; that then a fresh quantity is dissolved by the water, which is again absorbed, and so on, until all the alizarin has combined with the cloth, or until the mordants can take up no more. Hence the slowness with which madder-dyeing is effected. No doubt can, therefore, remain, that alizarin plays a great part in the production of madder colors. That it does not produce the whole effect in dyeing with madder, will be shown afterwards.

On subjecting alizarin to elementary analysis, SCHUNCK obtained the following results:—

I. 0·3205 gramme of crystallized alizarin dried in the air gave, on being burnt with chromate of lead, 0·6695 carbonic acid and 0·1210 water.

II. 0·3985 gramme of the same gave 0·8320 carbonic acid and 0·1850 water.

III. 0·3140 gramme gave 0·6565 carbonic acid and 0·1670 water.

These numbers correspond in 100 parts to—

	I.		II.		III.
Carbon,........	56·97	..	56·94	..	57·02
Hydrogen,......	4·19	..	5·13	..	5·87
Oxygen,........	38·84	..	37·93	..	37·11
	100·00		100·00		100·00

The great discrepancy in the amount of hydrogen in the preceding analyses, arises from the circumstance that alizarin loses its water of crystallization with such extreme facility. No. I. was mixed with warm chromate of lead in a warm mortar; No. II. was mixed with warm chromate of lead in a cold mortar; and No. III. with cold chromate of lead in a cold mortar. In the case of No. I., therefore, it is seen that the heat of the chromate of lead and the mortar combined was sufficient to drive away more water than that which corresponds to 1·5 per cent. of hydrogen, though this heat was not greater than what might be borne by the hand. In order to determine the amount of water of crystallization, crystallized alizarin was heated in a water-bath until it lost no more in weight.

I. 0·4015 gramme treated in this way lost 0·0735 water.

II. 0·3575 gramme lost 0·0655 water.

Alizarin which had been deprived of its water of crystallization by heat, gave, on being burnt with chromate of lead, the following results:—

I. 0·2990 gramme gave 0·7575 carbonic acid and 0·1045 water.

II. 0·3005 gramme of a different preparation gave 0·7620 carbonic acid and 0·1095 water.

III. 0·2765 gramme of the same preparation as the preceding, gave 0·7010 carbonic acid and 0·1025 water.

In 100 parts it contains, therefore—

	I.		II.		III.
Carbon, ...	69·09	..	69·15	..	69·14
Hydrogen, ...	3·88	..	4·04	..	4·11
Oxygen,........	27·03	..	26·81	..	26·75
	100·00		100·00		100·00

On analysing alizarin prepared by sublimation from pure crystals, SCHUNCK obtained the following numbers:

I. 0·3970 gramme gave 1·0115 carbonic acid and 0·1340 water.

II. 0·4110 gramme gave 1·0510 carbonic acid and 0·1375 water.

In 100 parts—

	I.		II.
Carbon, ...	69·48	..	69·73
Hydrogen, ...	3·75	..	3·71
Oxygen, ...	26·77	..	26·56
	100·00		100·00

It will be seen from this, that sublimed alizarin does not differ materially in composition from alizarin which has been freed from its water of crystallization.

Of the compounds of alizarin with bases, the lime, baryta, and lead compounds were prepared. The two former were prepared by dissolving alizarin in ammonia, and precipitating with chloride of calcium and chloride of barium, the latter by dissolving alizarin in alcohol, and precipitating with an alcoholic solution of acetate of lead. The latter forms a purple precipitate, which, after standing for some hours, becomes of a dull red.

The lead compound gave on analysis the following numbers:—

I. 0·4800 gramme gave 0·2095 oxide of lead and 0·0245 metallic lead, equivalent to 0·2359 oxide of lead.

0·5125 gramme burnt with chromate of lead, gave 0·7050 carbonic acid and 0·0780 water.

II. 0 5865 gramme of a different preparation, gave 0·3970 sulphate of lead, equivalent to 0·2920 oxide of lead.

0·6915 gramme gave 0·9370 carbonic acid and 0·1005 water. Hence was deduced the following composition:

	At. weight.		Theory.		Found.		
					I.		II.
14 Eqs. Carbon, ...	84	..	37·57	..	37·51	..	36·95
4 Eqs. Hydrogen,......	4	..	1·78	..	1·67	..	1·61
3 Eqs. Oxygen,........	24	..	10·75	..	11·70	..	11·65
1 Eq. Oxide of lead, ..	111·7	..	49·90	..	49·12	..	49·79
	223·7		100·00		100·00		100·00

The lime compound gave the following results:—

I. 0·4685 gramme gave 0·2065 sulphate of lime, equivalent to 0·0857 lime.

II. 0·4750 gramme gave 0·2125 sulphate of lime, equivalent to 0·0882 lime.

Assuming that the formula for this compound is $C_{14} H_4 O_3 + CaO + HO$, its composition would be as follows:—

	At. weight.		Theory.	Found.	
				I.	II.
1 Eq. Alizarin,	112	..	74·91		
1 Eq. Water,	9	..	6·03		
1 Eq. Lime,	28·5	..	19·06	.. 18·30	.. 18·58
	149·5		100·00		

The baryta compound gave the following:—

0·2450 gramme gave 0·1420 sulphate of baryta, equivalent to 0·0932 baryta.

Assuming that the formula of this compound is similar to that of the last, namely, $C_{14} H_4 O_3 + BaO + HO$, its composition would be as follows:—

	At weight.		Theory.	Found.
1 Eq. Alizarin,	112	..	56·65	
1 Eq. Water,	9	..	4·57	
1 Eq. Baryta,	76·68	..	38·78	.. 38·03
	197·68		100·00	

Neither of these compounds loses the equivalent of water which it contains on being heated in a water-bath for several hours.

The composition of crystallized alizarin must, therefore, be as follows:—

			Theory.
14 Eqs. Carbon,	84	..	56·75
8 Eqs. Hydrogen,	8	..	5·40
7 Eqs. Oxygen,	56	..	37·85
	148		100·00

Or,

	At. weight.		Theory.	Found.	
				I.	II.
1 Eq. Dry Alizarin,	121	..	81·76		
3 Eqs. Water,	27	..	18·24	.. 18·33	.. 18·32
	148		100·00		

It follows that alizarin dried at 212° must consist of—

	At. weight.		Theory.
14 Eqs. Carbon,	84	..	69·42
5 Eqs. Hydrogen,	5	..	4·13
4 Eqs. Oxygen	32	..	26·45
	121		100·00

If this be the true composition of alizarin, it follows that there exists a very singular relation between it and the composition of benzoic acid. The formula of benzoic acid is $C_{14} H_6 O_4$, and alizarin only differs from it therefore by containing one equivalent less of hydrogen. If alizarin be compared with isatin, it will be found that the latter only differs from the former by containing in addition the elements of one equivalent of cyanogen. The formula of isatin is $C_{16} H_5 NO_4 = C_{14} H_5 O_4 + C_2 N$.—*See Indigo.* Anthranilic acid differs in composition from alizarin in containing in addition the elements of amidogen, for the formula of anthranilic acid is $C_{14} H_7 NO_4 = C_{14} H_5 O_4 + NH_2$.

Alizaric Acid.—At one period of his investigation, SCHUNCK imagined that alizarin and rubiacin might be separated by boiling the mixture with perchloride of iron, in which case he expected the rubiacin to dissolve in the solution of the iron salt, and the alizarin to remain behind in combination with oxide of iron. He was not aware, at that time, that alizarin is decomposed by sesquichloride of iron. Before he had discovered this, however, he had taken about one hundredweight of madder, treated it with boiling water, added acid to the fluid, separated the brown precipitate by filtration, and treated the whole quantity of precipitate with sesquichloride of iron. The fluid was, after the addition of acid and filtration, evaporated to a sirup. After allowing the sirup to stand for some days, it was found filled with white crystals, bearing a resemblance to oxalic acid. Water was added to the sirup, which was filtered, and washed until the sesquichloride of iron was removed. The crystals bore washing with cold water without dissolving in any considerable degree. They were then dissolved in hot caustic alkali, filtered to separate some oxide of iron which remained behind, and sulphuric acid added to the fluid while still hot. On cooling, there separated a quantity of long shining white crystals, which were separated by filtration, and washed. SCHUNCK now found that they contained no oxalic acid, but that they bore a striking resemblance to benzoic acid. Indeed, some of the reactions are the same as those of benzoic acid, and it was only after having submitted it to an elementary analysis that he became convinced that it was not benzoic acid. The author termed this *alizaric acid.* It has the following properties:—

Its taste is acid. When heated on platinum foil, it melts and burns with a smoky flame, leaving no residue. When heated in a tube, it is completely volatilized, without leaving the least residue. The vapors condense in the colder parts of the tube, forming long white needles. This sublimate differs, however, in composition from the acid itself, and it may, therefore, be called *pyro-alizaric acid.* When heated in a tube with caustic lime, it is decomposed, and a yellow oil distils over, having a smell very nearly resembling that of benzin. It is soluble in boiling water; the solution has an acid taste, and reddens litmus paper. A concentrated boiling solution crystallizes on cooling. It is easily soluble in alcohol. Concentrated sulphuric acid dissolves it in the cold. On boiling the solution, no blackening takes place, and the alizaric acid distils over and crystallizes on cooler parts of the tube. It is easily soluble in alkalies. A concentrated alkaline solution gives crystals on the addition of a strong acid. The solution in ammonia gives no precipitates with the chlorides of barium and calcium. If, to the solution in water, chalk be added until all effervescence has ceased, the solution gives a crystallized lime salt on evaporation. This lime salt is decomposed on being strongly heated in a tube, becomes black, and gives an oil with an aromatic odor, which on cooling crystallizes. The aqueous solution gives with sesquichloride of iron a yellowish-white precipitate; with acetate of lead, a white precipitate; with nitrate of silver alone, no precipitate, but on the addition of ammonia, a white curdy precipitate, which, after some time, becomes crystalline. The reaction with sugar of lead distinguishes it from benzoic acid, which is not thereby precipitated. Its greater solubility in water, and its acid taste, are also distinguishing characteristics; but in most respects it will be seen that the resemblance between the two is very striking.

It is not necessary to prepare pure alizarin in order to obtain alizaric acid. SCHUNCK found the following to be the easiest method:—Nitric acid, of about specific gravity 1·20, having been put into a retort, garancin is introduced into the acid, and the liquid is heated until the red fumes have ceased to be evolved, and the color of the garancin has changed from dark-brown to yellow. The reddish-yellow acid liquid which is obtained, is filtered or strained to separate it from the woody fibre, *et cetera*, of the garancin, and evaporated to crystallization. A yellow crystalline mass is obtained, which is a mixture of oxalic acid and impure alizaric acid. After being washed with cold water to remove the excess of nitric acid, the mass is dissolved in boiling water, and chalk is added until all effervescence and acid reaction have ceased. The liquid is filtered, and the oxalate of lime remaining on the filter is washed with boiling water, until no more lime can be detected in the percolating liquid. The liquid is a solution of alizarate of lime. Hydrochloric acid is added to it, and it is evaporated to crystallization. A yellow mass is again obtained, which may be washed with cold water to remove the chloride of calcium, then redissolved in boiling water. It forms a yellow solution, which may be almost decolorized by animal charcoal. On again evaporating, the alizaric acid is obtained in large crystals. Should these crystals still retain a yellow tinge, which is generally the case, they must be redissolved in boiling water. By passing chlorine gas through the boiling solution, until every trace of color has disappeared, perfectly colorless crystals of the acid are obtained on cooling. Prepared in this way, it appears in large flat rhombic plates: it has the properties just described.

The salts of alizaric acid are mostly soluble. Alizarate of potash is formed by neutralizing a watery solution of alizaric acid with carbonate of potassa: it is obtained on evaporation as a deliquescent mass. Alizarate of lime is prepared by neutralizing alizaric acid with carbonate of lime, and evaporating to crystallization. It crystallizes in prisms possessing great lustre. Alizarate of baryta, prepared in the same way by means of carbonate of baryta, crystallizes in silky needles. Alizarate of silver, prepared by double decomposition, is soluble in boiling water, from which it crystallizes on the solution cooling. Alizarate of lead is an insoluble white powder, obtained by precipitation of the acid with acetate of lead. With ammonia, alizaric acid does not seem to form a neutral salt. On supersaturating a solution of the acid with ammonia and evaporating, the solution acquires during evaporation an acid reaction, and at length a salt crystallizes out in flat plates, which is probably a superalizarate of ammonia. All the salts of alizaric acid, when strongly heated, are decomposed with an evolution of a fragrant smell similar to that of benzin, and give, as a product of the decomposition, a thick brown oil, to which without doubt the smell is owing; while the carbonates of the bases, or the bases themselves, remain behind mixed with much charcoal.

The elementary analysis of alizaric acid gave the following results:—

I. 0·5250 gramme obtained by means of perchloride of iron and burnt with oxide of copper, gave 1·1015 carbonic acid and 0·1810 water.

II. 0·4670 gramme obtained by means of nitric acid and burnt with chromate of lead, gave 0·9865 carbonic acid and 0·1685 water.

III. 0·4475 gramme of the same preparation as the preceding, gave 0·9360 carbonic acid and 0·1625 water.

IV. 0·4395 gramme purified by means of chlorine and burnt with chromate of lead, gave 0·9335 carbonic acid and 0·1510 water.

These numbers give in 100 parts—

	I.	II.	III.	IV.
Carbon,......	57·20 ..	57·61 ..	57·10 ..	57·92
Hydrogen,....	3·83 ..	4·00 ..	4·03 ..	3·81
Oxygen,......	38·97 ..	38·39 ..	38·87 ..	38·27
	100·00	100·00	100·00	100·00

Alizarate of lead was analysed with the following results:—

I. 0·8110 gramme gave 0·2665 oxide of lead and 0·2160 metallic lead, equivalent to 0·4991 oxide of lead.

0·6660 gramme gave 0·5810 carbonic acid and 0·00915 water.

II. 0·6230 gramme gave 0·2040 oxide of lead and 0·1655 metallic lead, equivalent to 0·3822 oxide of lead.

0·6515 gramme gave 0 5560 carbonic acid and 0·0860 water. Hence was deduced the following composition:—

	At. weight.	Theory.	Found.	
			I.	II.
14 Eqs. Carbon,.......	84 ..	23·37 ..	23·79 ..	23·27
4 Eqs. Hydrogen,....	4 ..	1·11 ..	1·52 ..	1·46
6 Eqs. Oxygen,.......	48 ..	13·37 ..	13·15 ..	13·93
2 Eqs. Oxide of lead,..	223·4	62·15 ..	61·54 ..	61·34
	359·4	100·00	100·00	100·00

The baryta salt lost nothing in weight on being heated for several hours in a water-bath.

I. 0·6725 gramme of baryta salt dried at 212° gave 0·5245 sulphate of baryta, equivalent to 0·3442 baryta.

II. 0·7330 gramme gave 0·5700 sulphate of baryta, equivalent to 0·3740 baryta.

Its composition is therefore probably as follows:—

	At. weight.	Theory.	Found.	
			I.	II.
1 Eq. Anhydrous acid,..	136 ..	46·26		
1 Eq. Water,..........	9 ..	2·36		
2 Eqs. Baryta,..........	153·3	51·38 ..	51·18 ..	51·03
	298·3	100·00		

It is probable that the silver salt also contains two equivalents of base to one of acid.

It follows from the analysis of the lead salt, that the hydrated acid has the following composition:—

		Calculated.
14 Eqs. Carbon,................	84	57·93
5 Eqs. Hydrogen,..............	5	3·44
7 Eqs. Oxygen,.................	56	38·63
	145	100·00

By the action of nitric acid on alizarin, the latter takes up three equivalents of oxygen without losing any hydrogen, for $C_{14} H_5 O_4 \times 3 O = C_{14} H_5 O_7$. It appears also that alizaric acid contains one equivalent of hydrogen less, and three equivalents of oxygen more, than benzoic acid.

Pyro-alizaric Acid.—When alizaric acid is heated it is totally volatilized, and forms a sublimate in the shape of long white needles, to which SCHUNCK has given the name of pyro-alizaric acid. By the action of heat alizaric acid loses water, or the elements of water. Pyro-alizaric acid is soluble in boiling water. The solution, however, produces exactly the same reactions as alizaric acid itself, and, on evaporation, large rhombic crystals are obtained, which have quite the appearance of the latter acid. It is probable, therefore, that, by solution in water, pyro-alizaric acid takes up again the elements of water, and is reconverted into alizaric acid. The following results were obtained on analysing this acid:—

I. 0·4405 gramme dried at 212° and burnt with chromate of lead, gave 1·0345 carbonic acid, and 0·1185 water.

II. 0·4255 gramme gave 0·9985 carbonic acid and 0·1215 water.

From these numbers it may be inferred that the composition is as follows:—

	At. weight.	Theory.	Found.	
			1	II.
28 Eqs. Carbon,.......	168	63·87	64·04	63·99
7 Eqs. Hydrogen,....	7	2·66	2·98	3·17
11 Eqs. Oxygen,......	88	33·47	32·98	32·84
	263	100·00	100·00	100·00

Hence it follows, that by the action of heat two equivalents of alizaric acid lose three equivalents of water, and give one equivalent of pyro-alizaric acid, since $2\ (C_{14}\ H_5\ O_7) - 3\ HO = C_{28}\ H_7\ O_{11}$.

Rubiacin.—The other coloring matter found along with alizarin in the precipitate formed in aqueous extracts of madder by adding acids, and which Dr. SCHUNCK calls rubiacin, is prepared as follows:—The precipitate is boiled in alcohol till all soluble matter is taken up; the alcohol is then distilled, and the residue evaporated to dryness, when it has a dirty orange color; this is put upon a filter, and cold water poured upon it till it passes through colorless. That which is dissolved by the cold water is *rubiacin.* The mass left undissolved is then boiled in distilled water, and filtered hot; on cooling, it deposits alizarin. This process is repeated until the boiling fluid deposits nothing more on cooling. There are some fats also dissolved, and which disguise the alizarin. The insoluble matter left after treatment with boiling water, contains the rubiacin with fats. The alizarin is separated from the fats by boiling with an aluminous salt, which precipitates as a beautiful red color; the alumina is afterwards separated by a solution of caustic potassa.

The rubiacin is removed from the fats by a boiling solution of sesquinitrate or sesquichloride of iron, which produces a solution of a deep reddish color; this is filtered and treated with a little hydrochloric acid, producing a yellow precipitate, which is filtered and washed from the acid and iron salts. This precipitate is composed of rubiacin and rubiacic acid, the latter being formed by the action of the iron oxide on the former. It is now treated with boiling alcohol, which dissolves the rubiacin and the remaining fats, rubiacic acid being left. Rubiacin precipitates from the alcohol solution by cooling.

Rubiacin is most easily obtained in a state of purity from rubiacic acid. Rubiacin and rubiacic acid are mutually convertible, as they only differ from one another by a certain number of atoms of oxygen. Rubiacin is converted into rubiacic acid by the action of the sesquisalts of iron, and rubiacic acid may be reconverted into rubiacin by reducing agents, such as sulphide of hydrogen. In order, then, to obtain pure rubiacin, it is best to take a solution of pure rubiacate of potassa, to which a slight excess of caustic potassa has been added, and to pass sulphide of hydrogen gas through the solution for some time. Chloride of barium is then added, which produces a dark purple precipitate, consisting of rubiacin in combination with baryta. This is separated by filtration, and washed with cold water until the sulphide of barium and hyposulphate of baryta are removed, and then decomposed with hydrochloric acid, which leaves the rubiacin behind. After being washed with water, it is dissolved in boiling alcohol, from which it crystallizes on the solution cooling. It is obtained by these means in beautiful yellow crystalline plates and needles, having a strong lustre. The color is a little darker than that of neutral chromate of potash, and inclines more to green than to red. If there is a tinge of red in it, it is impure, and must be recrystallized. It has the following properties:—

It is a little soluble in boiling water, to which it communicates a reddish-yellow tinge. The solution deposits it on cooling in shining yellow scales. The alcoholic solution has a pure yellow color, without a tinge of red. It is precipitated from its alcoholic solution by water in yellow flocks. When heated on platinum foil it melts, and burns with a smoky flame, leaving no fixed residue. When heated in a tube closed at one end, it melts and gives yellow fumes, which condense in the colder parts of the tube in yellow crystals. If it be heated gradually at a moderate temperature, it may be almost entirely volatilized, leaving only a film of charcoal. Concentrated sulphuric acid dissolves it with a yellow color, and water precipitates it again in yellow flocks. The solution in sulphuric acid may be heated to the boiling point without becoming in the least degree black, and water still precipitates it. Concentrated nitric acid slowly decomposes it on boiling with an evolution of nitrous acid. Dilute nitric acid dissolves it with a yellow color on boiling, and on the solution cooling, it crystallizes out again in shining needles. It appears, therefore, that nitric acid does not convert it into rubiacic acid. Boiling acetic acid dissolves it, and deposits it again on cooling in yellow flocks. It is not affected by chlorine. It dissolves in a concentrated solution of sesquichloride or sesquinitrate of iron, forming a dark brownish-red solution, which on the addition of acid becomes yellow, and deposits yellow flocks. These flocks are no longer unchanged rubiacin, but rubiacic acid. It is a remarkable circumstance, that though rubiacic acid differs from rubiacin merely in containing a few atoms more oxygen, it is not formed from the latter by the action of nitric acid either dilute or concentrated, but is easily produced by the agency of the sesquisalts of iron, which seems to indicate that something besides the influence of oxygen is brought into play during the process. Rubiacin is soluble in carbonate of potassa with a blood-red color; the solution deposits after some time red flocks. It dissolves in caustic alkalies with a reddish-purple color, and is reprecipitated by acids in yellow flocks. The solution in ammonia gives with the chlorides of calcium and barium dirty red precipitates. The alcoholic solution gives with an alcoholic solution of acetate of lead, a dark-red precipitate. If into the boiling alcoholic solution hydrate of alumina be introduced, the alumina acquires an orange color, and the fluid is deprived of all its rubiacin. The compound with alumina thus formed dissolves entirely in caustic potassa, forming a purple solution, a characteristic which distinguishes it from alizarin, the alumina compound of which, as mentioned above, is insoluble in caustic potassa.

SCHUNCK arrived at the conclusion, that rubiacin cannot be considered as a true coloring matter, as it is impossible to dye with it. He has also shown that, contrary to the opinion which he was led to entertain in the first instance, rubiacin does not contribute to produce any effect in the process of madder-dyeing.

On subjecting rubiacate of potash and rubiacic acid to analysis, he obtained the following results:—

I. 0·4490 gramme rubiacate of potash gave 0·1090 sulphate of potassa, equivalent to 0·0589 potassa.

0·4350 gramme gave 0·7950 carbonic acid and 0·0900 water.

II. 0·3245 gramme gave 0·0790 sulphate of potassa, equivalent to 0·0427 potassa.

0·2890 gramme gave 0·5315 carbonic acid and 0·0665 water.

From these numbers it may be inferred that the salt is composed as follows:—

	At. weight.	Theory.	Found.	
			I.	II.
31 Eqs. Carbon......	186	51·63	51·50	51.82
7 Eqs. Hydrogen,..	7	1·94	2·29	2·55
15 Eqs. Oxygen,....	120	33·31	33·09	13·16
1 Eq. Potassa,......	47·27	13·12	13·12	13·16
	360·27	100·00	100·00	100·00

I. 0·3785 gramme rubiacic acid, dried at 212°, and burnt with oxide of copper, gave 0·7940 carbonic acid and 0·0845 water.

II. 0·3605 gramme of another preparation gave 0·7610 carbonic acid and 0·0795 water.

III. 0·4670 gramme of the same preparation as the preceding, gave 0·9775 carbonic acid and 0·1050 water.

Hence was deduced the following composition:—

	At weight.	Theory.	Found.		
			I.	II.	III.
31 Eqs. Carbon,...	186	57·76	57·21	57·57	57·08
8 Eqs. Hydrogen,	8	2·48	2·48	2·45	2·49
16 Eqs. Oxygen,..	128	39·76	40·31	39·98	40·43
	322	100·00	100·00	100·00	100·00

0·3150 gramme rubiacin, dried at 212°, and burnt with oxide of copper, gave 0·7740 carbonic acid and 0·0935 water.

This gives the following composition:—

	At. weight.	Theory.	Found.
31 Eqs. Carbon,.........	186	67·63	67·01
9 Eqs. Hydrogen,......	9	3·27	3·28
10 Eqs. Oxygen,........	80	29·10	29·71
	275	100·00	100·00

The formula of rubiacin being $C_{31}\ H_9\ O_{10}$, and that of rubiacic acid $C_{31}\ H_8\ O_{16}$, it follows that, when rubiacin is converted into rubiacic acid, it loses one equivalent of hydrogen and takes up six equivalents of oxygen, and that, when rubiacic acid is reconverted into rubiacin, it loses six equivalents of oxygen and takes up again one of hydrogen. This oxidation and reduction is accomplished with the same certainty and precision as any similar process with inorganic bodies.

Rubiacic Acid.—The method of obtaining this acid through the instrumentality of the sesquisalts of iron has been previously described. There is no reason for supposing that it exists as such in the plant. It is doubtless a product of the oxidation of rubiacin. To obtain it in a state of purity, pure crystallized rubiacate of potash is dissolved in water, and hydrochloric or any strong acid is added, which precipitates the rubiacic acid in the shape of a yellow powder. It has a pure lemon-yellow color. It cannot be obtained in a crystalline form. It is slightly soluble in boiling water, to which it imparts a yellow color. It is also slightly soluble in boiling alcohol, with a yellow color. The solution deposits nothing on cooling, but water produces in it an iridescent appearance, caused by the deposition of minute crystals. When heated on platinum foil, it melts and burns with a bright flame, leaving no residue. When heated in a tube it melts, and gives fumes which condense on the colder parts of the tube to an oil, which solidifies but does not crystallize. Concentrated sulphuric acid dissolves it with a yellow color, and water precipitates it again in yellow flocks. On heating the solution in sulphuric acid it becomes darker, but no gas is given off; some decomposition seems, however, to have taken place in consequence of the heating, for water now produces no precipitate. Concentrated nitric acid dissolves it on boiling, and slowly decomposes it with an evolution of nitrous acid. It dissolves in a solution of sesquichloride of iron with a dark reddish-brown color, and is reprecipitated by acids in yellow flocks. It is not affected by bichromate of potassa and sulphuric acids even on boiling.

The potassa salt is the only salt of this acid which SCHUNCK has hitherto examined. It crystallizes from a hot concentrated solution in water in needles and prisms of a light brick-red color. On being heated it is instantly decomposed, giving rise to a slight detonation. The aqueous solution has a blood-red color, but is quite transparent. The addition to it of caustic potassa causes it to assume a beautiful dark purple color, and a concentrated boiling solution does not crystallize on cooling after the addition of caustic potassa. The watery solution gives with solutions of the earthy and metallic salts the following reactions:—With chloride of calcium, it gives an orange-colored crystalline precpitate; with chloride of barium, a yellow precipitate; with sulphate of magnesia, a yellow precipitate; with alum, an orange-colored precipitate;

with protosulphate of iron, a greenish-grey precipitate; with sesquichloride of iron. a slight reddish-brown precipitate, which is soluble in the boiling fluid; with acetate of lead, a red precipitate; with sulphate of copper, a dull red precipitate; with nitrate of silver, a yellow precipitate, which is not changed by boiling; with subnitrate of mercury, a yellow precipitate; with protochloride of mercury, a crystalline yellow precipitate; with protochloride of tin, a dirty yellow precipitate; with bichloride of tin, a light yellow precipitate; with chloride of gold, a yellow precipitate, not changed by boiling the fluid.

SCHUNCK's analyses of rubiacin, rubiacic acid, and rubiacate of potassa, afford results which agree very well with one another. These analyses give for rubiacin the formula $C_{31} H_9 O_{10}$; for rubiacic acid, $C_{31} H_9 O_{17}$; and for rubiacate of potassa, $KO, C_{31} H_7 O_{15}$. It therefore appears that rubiacic acid contains seven atoms of oxygen more than rubiacin, and the facility with which they may be converted one into the other is easily conceivable. In rubiacate of potash, two atoms of water existing in rubiacic acid are replaced by one atom of potash, which is not usually the case with potash salts. SCHUNCK does not, however, consider these formulæ as completely established, since he was obliged, from want of material, to operate on such extremely small quantities.

Rubian.—This substance is obtained, as mentioned above, by treating the brown precipitate produced by an acid in an extract of madder with cold water, after having removed the excess of acid. It has the following properties:—

In thin layers it is perfectly transparent, and of a yellow color. When dry it is brittle. It is soluble in water; the solution has an extremely bitter taste. A concentrated boiling solution forms a jelly on cooling. It is precipitated from its aqueous solution by all acids, in yellow flocks. It is decomposed by nitric acid. In the watery solution, lime and baryta water produce red flocculent precipitates; sesquichloride of iron, a dark reddish-brown color, but no precipitate; acetate of lead, a brown flocculent precipitate; nitrate of silver, a flocculent precipitate; chloride of mercury, no precipitate; tincture of galls and solution of glue, no precipitates. The solution imparts a slight tinge to mordanted cloth, but so slight that this substance cannot be considered as a coloring matter. The solution deposits nothing during evaporation at all resembling apothem, and it therefore is not extractive matter. It dissolves in alcohol with a yellow color, and in alkalies with a red color. It dissolves in concentrated sulphuric acid with a red color; the solution, on being heated, becomes black, and gives off sulphurous acid. When heated on platinum foil, it melts, swells up immensely, and burns, leaving some ash. When heated in a tube, it melts and gives yellow fumes, which condense and form a crystalline sublimate, very much resembling rubiacin, so that SCHUNCK was induced to think that there is some relation subsisting between these two substances.

Pectic Acid.—There can hardly be a doubt that that part of the brown precipitate which is insoluble in alcohol, but soluble in water, is pectic acid, as will be seen from its behavior towards reagents, which is as follows:—It is soluble in water; the solution has a light yellow color, and reddens litmus paper slightly. In the watery solution, acids produce white flocculent precipitates; alcohol, a gelatinous white precipitate; lime and baryta water, thick gelatinous pink precipitates; common salt, a flocculent precipitate; nitrate of potassa, a flocculent precipitate; acetate of lead, a gelatinous reddish precipitate; sulphate of copper, a gelatinous greenish precipitate; chloride of mercury, no precipitate. On evaporating the watery solution, the substance separates on the surface of the fluid in the shape of a pellicle, and is left at last as a brownish extract, which may easily be detached from the sides of the vessel. In solutions of caustic and carbonated alkalies, it first swells up, and, on heating the fluid, it dissolves with a light-red color, forming slimy fluids, from which it is precipitated by acids in flocks. Solutions of salts, even of alkaline salts, produce precipitates in the alkaline solutions. It is decomposed by boiling concentrated nitric acid. When heated on platinum foil, it burns without melting, leaving a considerable ash. It seems that the pectic acid from madder retains in combination with it a portion of coloring matter, from which it cannot be separated. Hence the red color with which it dissolves in alkalies.

Rubian can be converted into different bodies by the action of acids upon it. Some of these are alizarin and rubiacin; and it is possible that some process may yet be found by which the whole of this apparently useless compound may be converted into useful products.

Besides the facts named, there are two kinds of resin, termed Alpha and Beta resin. The yellow coloring matter xanthin, soluble in cold water, has also been examined, and is stated to have the following properties and effects in the operations of dyeing:—

Xanthin has a disagreeable taste, between bitter and sweet. The watery solution is yellow. It is soluble in alcohol, and is left after evaporation in the same state as before. It is insoluble in ether. On adding hydrochloric or sulphuric acid to the watery solution, and boiling for some time, a peculiar smell is evolved, the solution becomes gradually dark-green, and a dark-green powder is deposited. This is the most characteristic property of xanthin. Nitric acid does not produce the same dark-green powder, or any deposit on boiling; nevertheless, the powder which has once been formed by means of hydrochloric or sulphuric acid, is not dissolved by boiling nitric acid, but only turned yellow. Acetic acid produces no effect. Oxalic acid gives a white precipitate of oxalate of lime. Bichromate of potassa and sulphuric acid produce no effect on a solution of xanthin, even on boiling. On adding caustic potassa to the solution it turns brown, and on boiling a slight smell of ammonia is evolved. Lime and baryta water, acetate and basic acetate of lead, the acetates of alumina, iron, and copper, nitrate of silver, chloride of mercury, and a solution of glue, produce no precipitate or effect whatever in a solution of xanthin. In fact, it does not seem to be precipitated by any reagent whatever without undergoing decomposition.

Mordanted cloth acquires no color in a boiling solution of xanthin, if the latter is in its yellow deoxidized state; but if the solution has become brown by contact with the air, then both the alumina and the iron mordant acquire in the boiling solution a brown color, while the unmordanted parts, which should remain white, become of a brown tint. Hence it follows that xanthin is injurious in madder-dyeing, and must contribute, together with the two resins, in impairing the purity of the colors, and sullying the whiteness of those parts which should attract no color. To get rid of the xanthin is one object of changing madder into garancin.

Dr. SCHUNCK concludes his papers with the opinion, that alizarin is the substance that produces the dye with madder. He says—

In order to prove analytically that alizarin is the substance which produces madder colors, several yards of cloth which had been dyed purple with madder, but not soaped, were treated with hydrochloric acid, which removed the oxide of iron, and left an orange-colored substance on the cloth. After washing the cloth in cold water until all the acid had been removed, it was treated with caustic alkali. The brownish-red solution thus obtained was supersaturated with an acid, and the reddish-brown precipitate formed was thrown on a filter, and well washed with cold water: it was then treated with boiling alcohol. The alcoholic liquid, which was dark-yellow, was spontaneously evaporated, and gave crystals of alizarin mixed with a powder resembling beta-resin, and a few yellow micaceous plates, which were probably rubiacin. There remained a brown residue insoluble in alcohol, part of which dissolved in boiling water, and proved to be pectic acid. On treating some cloth which had been dyed with madder and then soaped, with hydrochloric acid as before, and then with caustic alkali, was obtained a purple solution, in which acids produced a yellow precipitate. This precipitate was treated with boiling alcohol like the other; it gave a yellow liquid, which on evaporation afforded crystals of alizarin, together with white masses of fat acid. Hardly any residue remained undissolved by the alcohol.

Simultaneously with the investigation of Dr. SCHUNCK, Mr. HIGGINS undertook a series of experiments upon the same subject, with the results at once interesting to the chemist and useful to the dyer, as the following extracts will show:—

The various analyses of madder lead to the same conclusion as Dr. SCHUNCK, in his recent valuable paper *On the Substances contained in Madder*, namely, that there are three coloring matters capable of isolation—xanthin, a yellow; an orange, which he names rubiacin; and alizarin, a red. To this latter alone he ascribes all the tinctorial power of madder, an opinion from which Mr. HIGGINS differs; and the object of his present paper is to show that, under proper circumstances, the other two coloring matters have a great influence on its dyeing properties.

The difference in results seem to have arisen from the use, in one case, of boiling water to extract the principles, and in the other of cold or tepid water; the temperature having a remarkable influence on the products of extraction.

The Editor will here state the method employed by Mr. HIGGINS to separate from each other the three coloring matters; observing that, when separated, they differ little in their properties from those described by Dr. SCHUNCK.

The madder was on a conical calico filter, and washed well with boiling water till the liquor came away only faintly colored, and had no particular taste. Mr. HIGGINS objects altogether to boiling madder in water, as he finds that substances are obtained by so doing which have no existence in normal madder, being the result of decomposition: and the action ought to be as brief as possible. The extract by hot water, when cold, is acidulated with sulphuric acid, which causes a flocculent precipitate, which is collected on a filter. The precipitate contains rubiacin and alizarin, with some pectin. The deep yellow filtrate contains all the xanthin, slight traces of alizarin and rubiacin, some sugar, and the various organic and inorganic salts.

The filtrate is neutralized with carbonate of soda, and a very small quantity of hydrate of alumina added; the mixture is digested at a temperature of 130° Fahr. for about half an hour, and then filtered; by this means the traces of rubiacin and alizarin are removed, and the xanthin left, if not too much alumina has been used. To the filtrate is added baryta water, to throw down sulphuric and phosphoric acids; and after the separation of the baryta salts, sufficient subacetate of lead to throw down all the xanthin: some chloride and an organic salt are precipitated at the same time. The red lake is washed with a little cold water to remove some chloride of lead, sugar, *et cetera;* it is then diffused in water, and sulphide of hydrogen passed through; the xanthin remains attached to the sulphide of lead. This is thrown on a filter, and washed with cold water to remove the organic acid; it is then repeatedly boiled in water, and filtered. Xanthin dissolves with a rich yellow color. The solution is evaporated to a sirup in a water-bath, and, if necessary, neutralized with baryta, the evaporation completed, and the dry mass treated with absolute alcohol. Pure xanthin dissolves, and may be again evaporated to dryness.

The precipitate by sulphuric acid from the watery extract of madder is washed, first with water acidulated with sulphuric acid, and afterwards with a little pure water. About an equal bulk of fine chalk is then mixed up with it, and the mixture repeatedly boiled in water and filtered till the solution, at first dark-colored, becomes a faint pink only; the mixed solutions are acidulated with sulphuric acid, and the greenish-yellow precipitate collected, washed to remove acid, and dissolved in alcohol; the solution evaporated down to one-fourth of its volume, and an equal measure of water added. The precipitated rubiacin may be again dissolved in hot alcohol, and crystallized therefrom.

The alizarin is contained in the insoluble chalky matter left after the separation of rubiacin. This is digested with dilute hydrochloric acid at a gentle heat, cooled, filtered, and again treated with dilute acid, then washed on a filter till free from acid, alizarin remains, and may be crystallized from alcohol. It is obtained in much greater quantity from the madder which had been treated with boiling water at first. This washed madder contains principally alizarin, with a small quantity of rubiacin. It is boiled three or four times with a weak solution of alum to separate the rubiacin; it is next boiled with a saturated solution of alum for a quarter of an hour and filtered, and this process repeated till the madder is perfectly exhausted, and has become an ash-grey; the mixed liquors are cooled to 90° Fahr., and made sharply acid with sulphuric acid; after several hours the alizarin will have separated; the separation may be assisted by violent stirring occasionally. The filtered precipitate may be purified in the same manner as rubiacin.

Having described the isolated coloring matters, Mr. HIGGINS endeavors to show that the action of cold or tepid water on madder is attended with peculiar effects, and that by proper treatment all the xanthin and the greatest part of the rubiacin may be made to disappear, the change being accompanied by an increase in the tinctorial power; and since, of the three coloring matters, alizarin only can be made to dye colors, proving that alizarin and rubiacin result from changes in the xanthin.

When madder is mixed with cold water, stirred three or four minutes, and then filtered through fine calico, a deep reddish-brown liquid is obtained, tasting sweet at first, and then disagreeably bitter. A drop let fall upon white calico stains it a deep yellow, in the same way as a solution of pure xanthin does. When the liquid is allowed to stand an hour or two, it becomes gelatinous if the solution has been strong, and an orange-red flocculate precipitate falls. When this is filtered out, the liquor appears to have undergone a change, and is much diminished in intensity of color. It is now sweet only to the taste, without a trace of the bitterness so remarkable before; and a drop applied to calico stains it only a pale reddish color, with no shade of yellow. The powder filtered out has a very intense tinctorial power. The filtrate, on acidulation with sulphuric acid, gives more precipitate of the same nature, and remains a pale yellow, similar to the saturated solution of rubiacin and alizarin in a dilute acid. From some of the freshly-filtered solution of madder, xanthin was separated in the following manner:—Subacetate of lead was added to throw down all coloring matter; the lake washed and decomposed by sulphide of hydrogen, the metallic sulphide boiled in water several times, the mixed liquors neutralized with ammonia, and a small quantity of hydrate of alumina added; the mixture digested half an hour, and filtered from the lake of alizarin and rubiacin. On evaporation to dryness and treatment with alcohol, abundance of xanthin was obtained of the usual properties. The filtrate from the madder liquor which had stood till changed, was examined in like manner for xanthin, but without any being found. The red powder which had separated was dissolved in alcohol, precipitated by subacetate of lead, and the lake decomposed by sulphide of hydrogen. On boiling the sulphide in water, an orange liquor was obtained, from which, on cooling, flocks of rubiacin and alizarin fell; the pale orange liquor then evidently contained no xanthin. The sulphide boiled in alcohol yielded abundance of alizarin and rubiacin.

It was evident from this experiment, that in the madder liquor left to spontaneous action, all the xanthin had become changed into some coloring matter. To see what was the nature of this change, Mr. HIGGINS took some madder liquor quite freshly made in the cold, and added some solution of acetate of lime, which precipitates alizarin. The dark-red precipitate of alizarin lime having been separated, a dark reddish-brown solution remained: part of this was acidulated with hydrochloric acid, when a few yellow flocks fell, which when washed were found to be pure rubiacin. When mordanted cloth was attempted to be dyed with this powder, only the faint shades of rubiacin were obtained. The deep yellow filtrate from the rubiacin, when left to stand several hours, deposited no more flocks, and ultimately became green, as does solution of pure xanthin under the same circumstances.

Another portion of the filtrate from precipitation by acetate of lime was diluted a little with water, and allowed to stand about four hours; it had then lost the intense bitterness of taste, and retained only that of acetate of lime. On acidulation by hydrochloric acid, copious yellow flocks fell, which when filtered out left the filtrate a pale yellow; they were proved to be rubiacin, and had no tinctorial power. The yellow filtrate was examined for xanthin, but only a very small quantity was found.

Another portion of the original filtrate was set aside for about eight hours, when a quantity of reddish-orange powder had subsided, and the supernatant liquor was much diminished in intensity of color. The filtered precipitate, after treatment with dilute acid and washing, had a very strong tinctorial power; it was dissolved in alcohol, diluted a little with water, and lime-water added; a dark-red precipitate appeared, suspended in a red liquid. The filtered precipitate, washed with boiling water and decomposed by hydrochloric acid, was found to be pure alizarin; the filtrate from it, acidulated with hydrochloric acid, gave yellow flocks of rubiacin. The quantity of alizarin in the powder was greater than that of rubiacin; the liquor from which it had subsided was acidulated with hydrochloric acid, when a further quantity of powder was obtained, consisting of both rubiacin and alizarin, but more of the former. The filtrate from it was a pale yellow, and contained no traces of xanthin.

In these experiments, the madder liquor, from which all alizarin had been taken, and which had then no power to dye, by spontaneous action acquired a further portion of alizarin, and consequently recovered its power of dyeing. As the xanthin had totally disappeared during the process, the formation of alizarin must have been at its expense. The action is not however direct, as by stopping the process before any precipitation has occurred, only rubiacin is obtained, whilst, as before, xanthin has disappeared. It is evident, then, that the xanthin has become first rubiacin and afterwards alizarin.

This reaction does not result from oxidation, since it was found to take place equally well *in vacuo*; and as numerous experiments on the pure substance with various oxidizing agents failed totally to produce any alizarin, Mr. HIGGINS was induced to consider it the result of fermentation produced by a peculiar nitrogenized matter found in madder, and to be similar to the reaction between starch and diastase, where the starch becomes first dextrin and afterwards sugar.

This action becomes very probable from various experiments, in which it is found that the madder changes are best produced under circumstances favorable to the ordinary action of ferments, and are stopped by such substances as destroy their action.

In the foregoing experiments the changes undergone in cold water have been described, but, as in all other fermentations, a proper increase of temperature is attended with more rapid results. The best temperature is from 120° to 130° Fahrenheit. Water added to madder, and the mixture kept at that temperature, rapidly changes in appearance and taste; it gradually becomes redder, loses its bitter taste, and becomes more sweet; the yellow disappears, and the liquid, tested from time to time by dropping on white calico, is found constantly diminishing in intensity of color. In about half an hour all xanthin has disappeared; and the madder, if examined, is found to contain abundance of rubiacin and alizarin: if it was rich in xanthin, there will be at this stage a preponderance of rubiacin, so much so as to give an orange solution with boiling alum liquor, without much shade of pink. If the fermenting action be continued, the rubiacin is found gradually diminishing, and the alizarin proportionably increasing; the action is complete in about two hours and a half; and if the madder be now tried, only a small quantity of rubiacin is found; and the color of the alum solution is pink, but not quite so pure as that produced by pure alizarin, as the last portions of rubiacin are not easily removed by this process; a small fraction of the quantity originally found still remains.

Good madder contains sufficient ferment to convert an excess of xanthin into available coloring matter. Mr. HIGGINS made several experiments with different quantities, and found twenty per cent. additional to be the greatest quantity madder would convert.

With a view to place the utility of xanthin in dyeing beyond all doubt, the last-mentioned chemist made the following experiments:—

1. Two equal portions of the same madder were taken, and an equal quantity of water at 120° Fahr. added to each; to one, one-tenth of its weight of dry xanthin was added. They were kept at the same heat for half an hour, then in each was put an equal quantity of mordanted cloth of the same pattern, and they were heated gradually on a sand-bath, observing that the heating of the two dyeings progressed equally. At the end of an hour and a half, when the heat was 180° Fahr., the dyed cloth was removed, washed, and dried: the piece dyed with the ten per cent. additional xanthin was much darker and better dyed than that with madder alone; the whites were equally good.

2. The same experiment was repeated with twenty per cent. additional xanthin with increased advantage.

Two equal portions of madder were again taken: to one a certain quantity of water at 120° Fahr. was added, and the heat continued for half an hour; a certain quantity of dilute sulphuric acid then added, the mixture filtered, and the mass washed with a known quantity of dilute sulphuric acid, and afterwards with a known quantity of water.

The other portion was mixed with the same quantity of water and dilute acid as the former, filtered, and washed with the same quantity of dilute acid and water. The two portions thus treated were used to dye equal quantities of mordanted cloth, with the usual precautions. The one which was subjected to spontaneous action, previous to washing with acid, dyed full and rich shades; that from which the xanthin had been washed out unchanged, dyed shades very many times weaker.

In this experiment, the two madders were under exactly equal circumstances, except that one of them was allowed to ferment the xanthin; yet the difference in result was very great, and could only arise from the xanthin becoming available coloring matter. Mr. HIGGINS considers these experiments as clearly demonstrating the value of xanthin in madder-dyeing.

With this theory of madder, the operation of dyeing becomes much more intelligible. It is known that, to dye well with madder, the process must be begun at a low temperature, and the heat gradually raised. The application of the theory will be this:—The xanthin, on immersing the madder in water, immediately begins to decompose, becoming rubiacin; this in its turn becomes alizarin, and then the combination between it and the mordanted cloth takes place. The dyeing is begun by the alizarin already existing in the madder, and continued by the quantity continually formed. The slow heating of the liquor is very favorable to the change taking place. Generally, the temperature is about 130° at the end of the first hour; long before that, however, the xanthin has become rubiacin, and part of this alizarin, the remainder of the time being occupied in completing the change; the alizarin, being removed from solution as fast as formed, has probably some influence in accelerating the change of rubiacin. This will be the final action; and when the mordants are saturated, there will always be a small residue of rubiacin, which has a tendency to dull the shades; and hence the superior brightness of those dyed with garancin, which contains no rubiacin. Examination of the residual dye liquor generally shows a small quantity of rubiacin, which gives it an opaline appearance; there is also always alizarin united to woody fibre and lime. Examination of the dyed cloth, of whatever color, gives only alizarin, as was proved by SCHUNCK.

The fermentation and improvement of madder, when kept in the cask, is readily explained by supposing the xanthin gradually to change into alizarin: this is particularly noticed in Dutch madders, which abound in xanthin. Many substances and salts, added to a madder-dyeing, weaken its influence very much. An examination of the residual liquor uniformly shows the xanthin remaining unchanged, and the dyed effect has only been produced by the quantity of alizarin originally in the madder.

Having thus detailed experiments on normal madder, Mr. HIGGINS describes the results which he made on that preparation of it called garancin.

He found it to contain only one coloring matter, alizarin, and to be remarkably free from rubiacin, xanthin, pectin, and the nitrogenous matter. In no way was he able to separate any of these substances from the specimens he operated upon. The peculiar utility of garancin consists in all substances being removed which have an injurious influence on the action of alizarin.

As to the greater proportional dyeing power of garancin over madder, Mr. HIGGINS coincides in the opinion of Dr. SCHUNCK, that the lime salts being removed, no alizarin can remain combined with lime, and that in garancin dyeing all coloring matter is used up, whilst in madder only two-thirds are used.

Colorin.—It has been already stated that ROBIQUET and COLIN had obtained two tinctorial matters from madder, which they termed colorin and garancin. The former is considered to be impure alizarin; it is the substance left by distilling the alcoholic tincture made by treating garancin with spirit of wine. By dilution with water it is precipitated from the spirit, and when dried forms a dark-yellow mass; it is not much used in the arts.

Garancin.—ROBIQUET and COLIN, so early as 1828, not only prepared and described garancin, but, in conjunction with a French merchant, took out a patent for its manufacture and sale, under the name of *charbon sulphurique.*

The following is the process as described in their specification:—The madder is immersed in from five to six parts of cold water, and allowed to macerate all night, in order that the portion of the coloring matter which dissolves at first may have time to subside; the whole is then thrown on linen strainers, and when the liquor has percolated, the grounds are pressed: this operation is twice more repeated. After these three washings, which serve to remove a green substance, besides sugar, mucilage, and other soluble substances, the marc still moist and well crushed is mixed with sulphuric acid, equal to half the amount of madder first employed: it is, however, requisite that this acid should be diluted more or less with water, according to the temperature; this is done just before using it, in order to turn to account the heat set free by the mixture. The acid thus diluted is poured quite hot over the madder; it is then agitated as rapidly as possible, and when the mixture is well affected, the temperature is raised to 212°, and maintained for about half an hour. At the end of this time the substance is again mixed with a suitable quantity of water, filtered, and edulcorated on the strainers, until the liquid passes off perfectly insipid. It is then pressed, dried, and passed through a sieve.

In this operation, say the patentees, the acid has undergone no alteration; it has merely become weaker, and charged with some calcareous salts, which do not prevent its being employed in the manufacture of sulphate of soda. The first washing-water might also be turned to account, since it contains much sugar, which might easily be converted into alcohol.

Garancin was first introduced into commerce by the house of LAGIER and THOMAS of Avignon, towards the year 1829, who had bought the process and the patent from ROBIQUET and COLIN; but this product did not meet with success in the market. The neutral state in which it was delivered, not affording any correction to the calcareous waters ordinarily used in the Rouen print-works, and the action of their alkali on the coloring principle not being properly understood, the experiments which were made with it on a large scale were far from corresponding to those made with smaller quantities, and threw it into great discredit. It was not until about the year 1832, that the same house in Avignon, assisted by the advice of chemists, again commenced some trials, the results of which proving satisfactory, led to the belief that its use might become of importance. At this epoch, however, the madder-prints in vogue being very dark, and requiring a strong dye, could not be produced with garancin; the great quantity of tinctorial matter which they required, prevented its use on account of its price; but in 1835, the issue of certain kinds of prints requiring very bright colors, again drew the attention of manufacturers to garancin, and it was generally adopted and approved of.

Many persons, foreseeing how important its consumption might become, started establishments for the manufacture of it on the expiration of the patent of ROBIQUET and COLIN. Want of experience in this process caused these first manufacturers to obtain but imperfect products, and many soon left off; but shortly after, other speculatists, profiting by the experience of their predecessors, again took it up, and in 1843, according to GIRARDIN, there were from twelve to fifteen manufacturers of garancin at Avignon, and one or two in Alsatia.

The manufacturers of Avignon employ only the madders of the Comtat; those of Alsatia are, it is said, obliged to add a small quantity of the former to the madder which they grow, in order to increase the quantity of coloring matter of their product.

From 1839, this substance began to be generally employed in several of the principal print-works of Rouen, among others by SCHLUMBERGER-ROUFF, who manufactured the garancin which he used according to the following method:—

After having ground the already pulverized madder on a table by means of a thick wooden roller, it was placed in a leaden basin, then moistened with a little water, and half its weight of sulphuric acid, having a specific gravity 1·834, poured over it, whilst two men continually stirred the mass with shovels, walking around the basin. When the carbonization was ended, it was washed five or six times in barrels, the product drained upon linen, dried in a chamber by means of steam heat, and subsequently ground. This garancin was very acid, and could not be used for violet colors.

Since that period the manufacture of garancin has greatly extended; and although different modifications have been introduced as the result of observation in manufacture, very little change has been adopted upon the main principles of the manufacture upon that described above.

Up to the present time, it has not been possible to class garancin according to its quality. Each manufacturer seeks to obtain the best products with regard to the quantity of tinctorial principle, and also with regard to the brightness of the tints; but the impurity of the first matters, and the neglect of circumstances often in themselves very trifling, but, in reality, of great consequence, often cause the products of the same manufactory to vary considerably. In trade, garancin is met with which affords four times more coloring substance than the madder which was employed to obtain it, whilst other samples give but two and a half.

This want of regularity is as much dependent on the quality of the madder employed, as on the operations necessary in the production of the garancin; there is so much danger of charring the madder too much or too little by the acid, that it is quite impossible to produce two identical samples during a year. In large establishments, it is hardly possible to make fifteen or twenty barrels which will be nearly alike; for which purpose it is even necessary that the whole bulk of roots required should be treated at the same time. In general, a good garancin possesses three times as much tinctorial matter as madder of superior quality.

The same mode of classification has not been adopted for the garancin as for the madder; the former is only distinguished by the name of the manufacturer.

In 1843 a patent was taken for extracting garancin from the waste madders of the dye-house, which has been productive of great saving and advantage. The substance of the process thus patented is:—

The invention consists in manufacturing a certain coloring matter called garancin from refuse madder, or madder which has been previously used in dyeing, such madder having ordinarily been thrown away as spent and of no value, and the said coloring matter called garancin having been produced heretofore from fresh or unused madder. A large filter is constructed outside the building in which the dye-vessels are situated, formed by sinking a hole in the ground, and lining it at the bottom and sides with bricks without any mortar to unite them. A quantity of stones or gravel is placed upon the bricks, and over the stones or gravel common wrappering, such as is used for sacks. In a tub adjoining the filter is kept a quantity of dilute sulphuric acid, of about the specific gravity of 105, water being 100. Hydrochloric acid will answer the several purposes, but sulphuric acid is preferred as more economical. A channel is made from the dye-vessels to the filter. The madder which has been employed in dyeing is run from the dye-vessels to the filter; and while it is so running, such a portion of the dilute sulphuric acid is run in and mixed with it as changes the color of the solution and the undissolved madder to an orange tint or hue. This acid precipitates the coloring matter which is held in solution, and prevents the undissolved madder from fermenting or otherwise decomposing. When the water has drained from the madder through the filter, the residuum is taken from off the filter and put into bags. The bags are then placed in a hydraulic press, to have as much water as possible expressed from their contents. In order to break the lumps which have been formed by compression, the madder or residuum is passed through a sieve. To five hundredweight of madder in this state, placed in a wood or lead cistern, one hundredweight of sulphuric acid of commerce is sprinkled on the madder through a lead vessel similar in form to the ordinary watering-can used by gardeners. An instrument like a garden spade or rake is next used, to work the madder about so as to mix it intimately with the acid. In this stage the madder is placed upon a perforated lead plate, which is fixed about five or six inches above the bottom of the vessel. Between this plate and the bottom of the vessel is introduced a current of steam by a pipe, so that it passes through the perforated plate and the madder which is upon it. During this process, which occupies from one to two hours, a substance is produced of a dark-brown color approaching to black. This substance is garancin and insoluble carbonized matter. When cool, it is placed upon a filter and washed with clear cold water until the water passes from it without an acid taste. It is then put into bags, and pressed with a hydraulic press. The substance is dried in a stove and ground to a fine powder under ordinary madder stones, and afterwards passed through a sieve. In order to neutralize any acid that may remain, from four to five pounds of dry carbonate of soda for every hundredweight of this substance are added and intimately mixed. The garancin in this state is ready for use.—Sealed August 8, 1843.

GIRARDIN gives the following as the behavior of garancin towards reagents:—

Cold distilled water communicates, after twenty-four hours of contact, a pale yellowish color; with boiling distilled water, it gives a pale reddish-yellow tint; cold calcareous water tinges it after twenty-four hours, but less than cold distilled water; boiling calcareous water occasions a somewhat paler hue than distilled boiling water; the tint with cold lime-water is paler after twenty-four hours than that with distilled boiling water, or that with boiling calcareous water; water acidulated with sulphuric acid, gives, after some hours, a slightly greenish-yellow; water acidulated with hydrochloric acid, reacts in a similar manner, but the tint is darker; cold distilled water acidulated with nitric acid, causes a rather dark tint, and the blackish-grey powder becomes of a brownish-red, resembling madder browned by age; with cold distilled water acidulated with acetic acid, the tinge becomes faint-yellow; acetic acid of 1·0704 specific gravity, gives, after several hours, a beautiful reddish-yellow color; caustic ammonia immediately occasions a reddening, and after twenty-hours the liquor is strongly colored crimson-red, so intense, that it is no longer transparent in a great mass; on the addition of water slightly alkalized by ammonia, it immediately assumes a beautiful claret color; caustic soda communicates a dark reddish-brown hue; with water charged with carbonate of soda, it quickly acquires a bright reddish color of Burgundy wine; cold alum-water causes it to become almost immediately a chrome red; boiling alum-water gives with it immediately a dark-red hue, and on cooling, flakes of the same color, but paler, are deposited; with alcohol of specific gravity 0·863, it assumes rather quickly a slight reddish-yellow tint; hydrated ether gives the same reaction.

As illustrative of the applications which some of these investigations upon madder have given rise to, the two following patents are quoted:—

JULIAN took a patent, in 1851, for extracting the coloring properties of madder, and for obtaining a spirit from the water that has been used in the extracting operation. The latter has been noticed under the article ALCOHOL. See page 116.

Whatever the quality of the madder, it may be treated according to this invention, which is carried into effect as follows:—Two hundredweight of madder, reduced to powder, are thoroughly mixed or diluted with from one hundred and thirteen to one hundred and eighteen gallons of water—according to the fineness of the powder—and the liquid is then run through a filter of woollen cloth, fixed upon a frame within a tun or vessel which receives the water, and is furnished with a tap for discharging the same. The filter is constructed to contain six hundredweight of madder, so that, when the above operation has been thrice performed, it will be full. The water is then drawn off into large wooden tuns, and the residue, which is now a wet paste, is put into linen bags or baskets, and subjected to the action of a hydraulic press, in order to extract the remaining water which is added to that before drawn off. After the paste has been well pressed, it is placed in receptacles heated to from 120° to 160°; and when it is perfectly dry, it is reduced to powder, and passed through a sieve. The patentee states, that a given quantity of this product—which he calls *flowers of madder*—when employed in dyeing, will have a greater effect than a like quantity by weight of the madder from which it has been extracted.

The water collected from the filter and hydraulic press is put into large wooden tuns, placed in a room heated to from 70° to 85°, where it is retained until alcoholic fermentation takes place, or for the space of five or six days. If by that time the alcoholic fermentation is not produced, the patentee puts into the tun five gallons of boiling water, in which ten or twelve pounds of yeast have been dissolved. On finding that the density of the water is reduced to a certain point, it is known that the alcoholic fermentation has been produced; and the liquid is then submitted to the process of distillation, in order to obtain a spirit therefrom.

A patent was granted in 1852, to C. A. KURTZ, for the preparation of madders and munjeet, by combining therewith preparations having a tendency to produce fermentation. For this purpose a liquor is first made in the following manner:—Twenty pounds of crushed malt are boiled in one hundred gallons of water from twenty to thirty minutes; after which, about forty pounds of bran are stirred in, and the menstruum allowed to stand until the malt and bran fall to the bottom, after which the clean liquor is run off, and the remainder filtered. From sixty to sixty-five gallons of the infusion are added to one hundred gallons of water, which is of such a temperature that the mixture will be about 112°. This is put into a vessel capable of containing about two hundred and sixty to three hundred gallons, and about three hundredweight of madder or munjeet are added, and the whole stirred at intervals of from ten to fifteen minutes, until it becomes homogeneous. This is to be left to rest till signs of fermentation appear; these are to be checked by repeated agitation during a period of from sixteen to eighteen hours; the mass is then to be filtered, pressed, dried, ground, and packed in the usual way.

The patentee remarks, that in place of malt and bran, other grain or matters may be employed in preparing a mash or liquor, which will tend to produce fermentation in like manner, though he believes that malt and bran are the best for the purpose. He further observes, that although he has been particular in stating the materials and exact quantities and temperatures, according to the best of his knowledge, he does not confine himself thereto, as they may be varied without departing from his invention, so long as extraneous matter be employed to induce fermentation.

Adulteration of Madder.—On account of the high price of madder, and especially from the facility of introducing into it, when sold in the form of powder, foreign pulverulent matters, which the most practised eye cannot detect, this root is subject to a number of sophistications which cannot be too fully exposed.

There are two kinds of adulteration. Sometimes earthy or mineral matters are incorporated with ground madder; at others, vegetal substances having a semblance of color are added to it.

According to GIRARDIN, the inorganic substances which have been introduced, or which are still found in powdered madder, are brick-dust and yellow ochre, yellowish sand, clay, or argillaceous earth. A madder which contains earthy substances grates between the teeth when chewed.

A small quantity introduced into a large test glass, and diluted with about one hundred times its weight of water, quickly deposits the greater portion of the earthy substances at the bottom of the vessel. When the suspended madder is decanted, and the deposit agitated with a fresh quantity of water, the earthy substances are isolated, and may be examined.

However, to determine the proportion, more exact processes must be had recourse to. The best is that of incinerating a portion in a platinum crucible.

Five grammes of the madder under examination are first dried completely at 212°, weighed with great exactness, and then put into the platinum crucible, previously tared; the lid is then superposed, and heat gradually applied. When perfectly incinerated, the crucible and its contents are allowed to cool, and then weighed. The weight of the crucible and ash being deducted from the gross weight of the crucible employed, gives the proportion of inorganic residue. This contains the fixed mineral matters of the root, and also the earthy substances foreign to the chemical constitution of the root, and which have been accidentally or fraudulently mixed with the madder.

Some experiments which GIRARDIN and LABILLARDIÈRE made on a large scale in 1828, showed that madder which is very pure, and quite free from epidermis, or any foreign earthy matter, and dried with care, gives, by incineration, five per cent. of ash; that the lizari of Provence, stripped of its pellicle, gives, on an average, 8·80 per cent. ash.

According to SCHLUMBERGER, one hundred parts of Alsatian lizari, washed in distilled water, and dried at 212°, gave 7·20 per cent. of ash; whilst one hundred parts of lizari of Avignon, prepared in the same way, afforded 8·766.

According to CHEVREUL, lizari from the Levant, dried at 212°, gives 9·80 per cent. of ash.

When an Avignon madder, SFF, the mark most generally used, subjected to the test of incineration, gives a greater weight of ash than five per cent., which **Girardin** took as the means of numerous experiments, the excess must be attributed to the presence of foreign earthy or sandy matters, either arising from adulteration or a careless preparation of the powder.

When the excess over this is only from three to four per cent., it is probably due to some fault in the preparation of the madder, the manufacturer not having sufficiently separated the epidermis—which is always coated with the earth which surrounds the root—by grinding; but when the ash amounts to nine or ten per cent. of the madder employed, it is the result of fraud.

The madders of Avignon obtained from the merchants give very variable results with respect to the proportion of ash which they furnish, as the following table shows:—

		Per cent. of ash, Girardin.
In six experiments	the mulle madder gave	4·00
" seven "	" SF "	" 12·40 to 20·00
" eighteen "	" SFF "	" 7·40 " 23·00
" four "	" SFFRP	" 12·00 " 16·00
" three "	" SFFP "	" 10·00 " 10·80
" seven "	" EXTF "	" 10·00

The vegetal substances which are introduced into the madders are powders of little or no value, such as sawdust, almond shells, bran, the bark of the pine-tree, mahogany, red saunders, fir, and logwood.

The sophistication by these different matters is much more prejudicial to the dyer than that by mineral ingredients; for besides diminishing, like the latter, the quantity of coloring principle in a given weight of madder, they also injure the dye, either by absorbing the coloring matter, or by preventing the hues becoming so brilliant.

Unfortunately, the means of detecting this kind of fraud are neither so rigorous nor so simple as the process for determining the presence of mineral adulterants. It is extremely difficult to find with what kind of vegetal substance a madder has been deteriorated; it is mostly only possible to discover that there is a mixture, and the best way is to ascertain the tinctorial power of the sample under examination. Many methods have been proposed for this purpose, but the greater part of them have some defect, generally being too difficult, and too long of execution. That of **Robiquet** and **Colin** may be performed in the following manner:—Dry the samples at 212°, and treat them with two hundred or two hundred and fifty grammes of water, the temperature of which should not exceed 68°, otherwise a portion of the red coloring matter would be dissolved. The whole, after having been left in contact for about three hours, is thrown upon a filter, the insoluble portion is washed with two hundred or two hundred and fifty grammes of cold water, after which it is dried in the water-bath and weighed.

One part of the insoluble matter is then put into a small glass balloon, with forty parts of water and eight of alum; the whole is heated, and after boiling for a quarter of an hour, the liquor is filtered whilst in a state of ebullition.

The residuum on the filter is again washed as before, and the filtrate from the various samples is precipitated by sulphuric acid. The weight of the subsidence so produced in each liquor represents the proportion of coloring matter.

This mode is based upon the insolubility of alizarin in cold water, whilst the boiling solution of alum dissolves it all.

Chevreul, however, says that a portion remains undissolved.

Meillet's process is the following:—Take about four and a half gallons of water, heated to 140°, and dissolve in it about four and a half pounds of alum; add thereto about twenty-two pounds of madder, bring the whole gradually to the boiling point, and keep it at that temperature for half an hour. The whole is then thrown upon a cloth filter, and pressure applied to the solid matter; after having repeated this treatment three times, the madder is exhausted. After the various filtrates are mixed together, and left at rest for a while, the clear portion is decanted, and before it has completely cooled, the operator pours into it six hundred and twenty-five grammes of sulphuric acid, having a specific gravity of 1·848, diluted with twice the bulk of water, taking care to stir the liquor incessantly whilst adding the acid. Thick reddish flakes are precipitated, which soon subside, and the menstruum from red-purple becomes greenish-yellow. The supernatant liquor is then decanted, the residuum is washed several times, and a mass is left which, after drying in the air, is in the state of shining scales of a reddish-brown color; it is alizarin, but not quite pure. The precipitate, whilst still moist, should be heated with once and a half its weight of carbonate of potassa, dissolved in twelve or fifteen times its bulk of water; the alkaline carbonate is converted into sulphate, which produces a fine red precipitate, and this, according to **Meillet**, is pure alizarin, of which Avignon madder, when submitted to this treatment, yields two or two and a half per cent.; but it is necessary, in such trials, to compare the result obtained with that given by samples of the same kind and name which are known to be genuine. The coloring power of madder may also be determined by the colorimeter of **Labillardière**, which has been described in the treatise on **Indigo**, see page 588. The type madder, and that under examination, are dried at 212°, and a note is kept of the respective quantities of hygrometric water they contain.

Twenty-five grammes of each sample are then mixed with two hundred and fifty grammes of water at 68°. After three hours of contact, the whole is thrown upon a linen cloth. A second maceration is made with the same amount of water, and for the same period. The madders are then washed with two hundred and fifty grammes of cold water, dried at 212°, and weighed, in order to ascertain the proportions of soluble, saccharine, and mucilaginous matters which they have lost by these preliminary washings, which, however, only remove an insignificant amount of tinctorial principle.

Five grammes of each of the two madders are then introduced into glass globes with forty parts of water, and six parts of pure alum, boiled for a quarter of an hour, and the liquids filtered. The grounds are washed with two parts of hot water. Two other decoctions, similar to the first, are made, and each time the residue is washed in a similar manner. The products of the three decoctions are combined, and the liquids from the two samples compared by the colorimeter, by means of which it is easy to appreciate the different intensity of color; for if one hundred parts of the mixed decoction of each sample be introduced into the tubes, and water added to that which has the deeper tinge, until it is brought exactly to the degree of intensity of the other, the graduations will at once indicate in what ratio they differ.

But as madder is often adulterated with pulverised dyewoods, such as logwood, Brazil-wood, *et cetera*, other trials should be simultaneously resorted to. GIRARDIN dyes with a given weight of pulverised madder, known to be of superior quality, a certain quantity of cotton prepared with different mordants. The pieces of calico employed for the experiment should all be of equal weight, and about two and a half or three inches square, and should be dyed with increasing proportions of madder, from ten to one hundred and fifty grains; a scale of intensity of color is thus prepared with each mordant, the degrees of each scale corresponding to a known weight of the madder taken as type.

The dyeing must be performed with care as follows:—Take a suitable number of wide-mouthed flasks, and put them into a pan placed over a naked fire, and containing water at 100° or 104°. Pour into each of the flasks one and a half pint of distilled water, also a piece of the mordanted piece of madder required. Place a thermometer into the pan, which should now be carefully heated, avoiding variations of temperature, and in such a way that an hour and a half may elapse before the bath attains 167°. After this period, the temperature must be raised to the boiling point for half an hour. The samples of calico are then withdrawn, rinsed with cold water, and dried.

After this treatment they are divided into two equal portions; one-half is preserved in that state, the other is immersed for half an hour at 106°, in a solution consisting of twenty-five grains of curd soap, and one and a half pint of water: the tissue is next taken out, rinsed with cold water, and returned to a similar bath, but to which eight grains of tin have been added. This bath is kept boiling for half an hour. The piece of calico should be carefully rinsed, dried, and kept sheltered from the light.

After having prepared a scale as above directed, it is sufficient afterwards, in order to determine the value of a sample of madder, to dye pieces of calico of the same description, with known weights of the madder under examination, and this value, compared with that taken as type, is then easily determined.

Instead of remnants of calico, skeins may be employed, weighing one hundred and fifty grains, for which, from three to four hundred and fifty, or five hundred grains of pulverised madder are used to form a scale of the colors.

Considering the minutiæ and the number of operations which it is necessary to have recourse to, in order to form a just estimate of the relative worth of madders, it is evident that an examination of them by a simple inspection, as is customary with the merchants, can afford no precise information, and must indeed lead in many, if not in most cases, to erroneous conclusions. The commercial process consists in placing samples of madders—each about thirty or forty grammes—side by side on a sheet of paper, in small heaps, which are flattened, and their surfaces rendered smooth with the back of an ivory spatula. They are then removed to a cellar, or some moist situation, where they remain from twelve to fifteen hours. At the expiration of this time, the quality is judged of according to the brightness and tint of the powder.

But, as SCHLUMBERGER has observed, this method does not even approximately show the richness of the madders, since a somewhat long contact with the air is sufficient to render them darker, and many circumstances may change their tint, without thereby causing a variation in their tinctorial value. On the other hand, the old madders, of a dull tint, may be far superior to others of a more beautiful color. The merchant's and broker's method of trial often places the manufacturer in a false position, by obliging him to brighten the hue of his powders, in order to make them more saleable, and that sometimes to the injury of the tinctorial power, thus facilitating the adulteration of the madders by mixture with foreign substances, suitably colored and pulverised, which serve to heighten the tint of the powder, and it is impossible to ascertain the presence of these mixtures by exposure in the cellar. GIRARDIN purposely made mixtures of madder, of powders of mahogany, and of sandal-wood in known proportions, and these compounds, when tried by the merchants, who thought themselves very skilful in their estimation by the above process, were considered by them to be pure madders of first quality.

Indeed, as before observed, the truest way of arriving at the value of madder, is by a direct estimation of the amount of coloring matter. The most exact process hitherto known is that published by SCHLUMBERGER in 1836, and as modified by SCHEURER. But this method, which is founded on the solubility in weak acetic acid of the tinctorial principle of madder, is unfortunately too sensitive, and requires such an amount of manipulative skill as to prevent its becoming generally employed.

The mode of procedure adopted by GIRARDIN is as follows:—

Fifty grammes of madder are treated with fifty grammes of concentrated sulphuric acid. The whole is left in contact for some hours, too elevated a temperature being carefully avoided; the charcoal obtained is mixed with water, and thrown upon a filter; it is then washed until the water passes through quite insipid, and next dried at a temperature of 212° in the water-bath. It is afterwards reduced to a fine powder, and macerated for two hours, at three distinct intervals, with cold alcohol, containing a little ether, in order to free it from fatty matter which it retains. The powder is thrice boiled in alcohol, having a specific gravity of 0·834, employing each time about two hundred and fifty grammes. When this is no longer colored by ebullition, the alcoholic liquors are mixed, distilled in a small glass retort to the consistence of a sirup, and the concentration of the liquid completed in the water-bath, in a weighed porcelain crucible. When the extract is perfectly dry, its weight is ascertained. This represents the proportion of tinctorial principle contained in the weight of madder originally taken; the per centage is easily known.

This process is rather long, and does not give, especially on a small scale, the absolute proportion of coloring substance contained in the madder; there is also a slight loss, but by acting comparatively, a sufficient approximation is obtained.

These processes, which require great care and nicety of manipulation, are not suitable to the ordinary workmen, and can only be attempted in such works as employ practical chemists. What is required is an easy method, so simple in manipulation that a dyer with ordinary intelligence and hands can perform it. The only process yet recommended, and suitable for ordinary use, is that of dyeing samples of the same weight of cloth or yarn previously mordanted; and, for this purpose, every dyer should keep beside him samples of madder of known good quality for comparison; and by so doing, and by using mordants of a different sort—such as the aluminous and iron—not only the depth of tint may be well ascertained, but also the presence of other dye-woods by the well-known peculiarity of tint which they give with these mordants.

MUNJEET.—This is the root of the *Rubia munjista*—cordifolia—called sometimes *Indian madder*, on account of its being used by the Indians, and even preferred by them to madder for some of their dyeing operations. It is found in commerce in bundles, consisting of stalks of two or three feet in length, and varying from the thickness of a quill to that of the little finger. The red coloring matter it contains is somewhat similar to that of madder, being alizarin. It may be separated in the same way by the action of sulphur, forming garancin, for which purpose it is extensively employed; but the quantity obtained from it is not so great as from inferior madder. It dyes a very bright color, of a scarlet tint. The dyeing quality of the roots is much improved by first heating them to ebullition with a little water having sumach in it, and afterwards adding the required quantity of water for dyeing and entering the goods. It is not much used, however, in the state of a root either for cotton or woollens, but is mostly converted into garancin, the quality of which is somewhat similar to that obtained from spent madder, the tint of color it produces being a little brighter.

PITTACAL.—This is a beautiful coloring matter obtained from tar. When the latter substance is freed from acid, and baryta water added to it, there is produced a precipitate of a deep blue color. When collected and dried, it forms a deep blue solid mass, strongly resembling indigo, assuming also a coppery lustre when rubbed. It has often been mistaken for indigo by the dyer; from which, however, it may be very easily detected by a few simple tests. It has neither smell nor taste; it is insoluble in water, but may be suspended in that liquid in such a state of division as to pass through a paper filter. It dissolves in acids, giving colored solutions. With acetic acid it gives a deep rose color, from which it is again precipitated of a fine blue. It is in this way very sensitive to acids and alkalies, and has been recommended as equal, if not superior, to litmus as a test agent. It is not subject to alteration by air and light, a property valuable in dyeing. It gives a violet-blue with acetate of lead, chloride of tin, acetate of alumina, and ammoniacal sulphate of copper; thus its application to dyeing is easy, still its introduction as a tinctorial agent has not yet been attended with that success which its discoverer had anticipated.

QUERCITRON is the inner bark of the *Quercus nigra* or *tinctoria*. The tree is a native of North America, but has been introduced into France and Bavaria. Its dyeing powers were first published by BANCROFT in 1784; and a law was passed by Parliament, in 1786, securing to him the exclusive use and application of it as a dye-stuff, for a certain term of years.

A decoction of quercitron bark has a yellow-orange color: if it be made very strong, it deposits a portion of the tinctorial matter on cooling. It contains a great quantity of tannic acid, which is always dissolved in the menstruum, and which gives the solution of bark a greater variety of uses. A decoction of the bark gives the following reactions:—Alkalies deepen the color of the solution; lime occasions a yellowish-red precipitate; protochloride of tin causes a yellowish-red subsidence; alum produces a slight deposit in the cold, but more when hot. Acetates of alumina and lead afford reddish-yellow precipitates, while that given by the same salt of copper is greenish-yellow. Salts of iron throw down a dark olive-green precipitate, passing into brown. Sulphuric, hydrochloric, and nitric acids, cause the formation of reddish-yellow flocculi.

CHEVREUL gave the name of *quercitrin* to the yellow coloring matter of quercitron bark. He obtained it in small laminæ or scales, of a pale greyish-yellow. by slowly concentrating an infusion or decoction of the bark, and allowing it to cool. According to this chemist, this substance is accompanied in the bark by red tinctorial bodies, and by brown principles. These owe their origin, in part at least, to the alteration of the quercitrin. The stale infusion of quercitron gives but a small quantity of dye; a great portion of the quercitrin is deposited, and that remaining in solution is of a dark hue, and its dyeing quality is much impaired.

In 1840, BOLLEY instituted some experiments on the yellow coloring matter. He obtained it by exhausting the pulverised bark with strong alcohol in a displacement apparatus, precipitating the tannin by gelatin or by a little lime, and evaporating the filtered liquid. This procedure causes the deposition of yellow crystalline crusts, which may be purified by washing with water, then dissolving them in alcohol, adding some water, and evaporating the solution, which affords a crystalline powder of a sulphur color, approaching to a chrome-yellow. BOLLEY applied the name of quercitric acid to this substance, because it reddens litmus perceptibly, and combines with bases. He represents it by the formula $HO, C_{16} H_8 O_9$, and its lead salt by $Pb O, C_{16} H_8 O_9$.

PREISSER obtained quercitrin in the following manner:—A small quantity of gelatin was first added to the aqueous decoction of quercitron, so as to precipitate all the tannin. The filtrate was then treated with a little hydrate of lead, which produced a dirty-brown precipitate. The decanted liquor was of a very beautiful golden-yellow color, and yielded an abundant brilliant yellow deposit on the addition of hydrate of lead. This last lake, when well washed and decomposed by a current of sulphide of hydrogen, afforded a colorless liquid, which, on evaporation *in vacuo*, gave white needles of pure quercitrin.

According to the last-mentioned authority, quercitrin is colorless, and has at first a slightly sweet, subsequently a bitter taste. It is very soluble in water, in alcohol, and in ether. In contact with the atmosphere, it gradually becomes bright yellow, and by degrees the solution deposits yellowish-white flakes, having a crystalline appearance. The aqueous solution, if left a long time in contact with air, acquires a dark-yellow hue.

Mineral acids dissolve it, giving it a yellow color; alkalies, in contact with the air, turn it to a dark brown-yellow. Lime-water effects a similar change; acetate of lead occasions a white precipitate, which may be dried in a tube filled with nitrogen, without becoming perceptibly colored; but by exposure to the atmosphere, it acquires a yellow tint after a few hours.

On boiling a solution of quercitrin, it becomes turbid, and deposits a large quantity of small acicular crystals of quercitréin, less soluble in water, and which forms with hydrate of lead a beautiful golden-yellow quercitrate of lead.

These facts, therefore, show, says Preisser, that in the bark of the quercitron there is but one tinctorial principle, colorless in the heart of the wood, and which only passes into the yellow state—quercitréin—by the assimilation of oxygen. The brown matter is a mixture of the last-named principle and of tannin, or rather of quercitrate of lime tinged brown by altered tannin.

Quercitrin and quercitréin are for the greater part volatile. They contain no nitrogen.

The colorless quercitrate of lead consists of—

	At weight.	Centesimally.	
		Theory.	Preisser.
64 Eqs. Carbon,............	384 ..	51·20 ..	51·11
30 Eqs. Hydrogen,.........	30 ..	4·00 ..	3·99
28 Eqs. Oxygen,...........	224 ..	29·87 ..	29·84
2 Eqs. Oxide of lead,......	112 ..	14·93 ..	15·06
1 Eq. Quercitrate of lead,..	750	100·00	100·00

The formula of quercitrin is, therefore, $C_{32} H_{15} O_{14}$; and that of the lead compound $2 PbO, (C_{32} H_{15} O_{14})$.

Quercitréin was first obtained by Chevreul from a decoction of one part of the bark in five of water, which, after some days, deposited the yellow principle in a crystalline state. Quercitréin is either crystalline or pulverulent, yellow, inodorous, and slightly bitter. It is much less soluble in water than quercitrin, and dissolves in from four to five parts of alcohol; its solution is slightly acid, and after long exposure to air becomes reddish-brown; alkalies give it a greenish-yellow hue; it is entirely deprived of color by hydrated oxide of lead, which occasions in it a golden-yellow precipitate. Nitrate of silver causes a brown subsidence which soon decomposes, and the metal is reduced. With acetate of copper and chloride of tin, it gives a yellow, and with sesquisulphate of iron an olive-green deposit. A solution of alum brightens the color of a solution of quercitréin, and on adding an alkali there is a fine yellow precipitate. The yellow quercitrate of lead consists of—

	At. Weight.	Centesimally.	
		Theory.	Preisser.
32 Eqs. Carbon,............	192 ..	41·46 ..	41·53
15 Eqs. Hydrogen,.........	15 ..	3·25 ..	3·33
18 Eqs. Oxygen,............	144 ..	31·10 ..	31·20
1 Eq. Oxide of lead,......	112 ..	24·19 ..	24·94
1 Eq. Quercitrate of lead,..	463	100·00	100·00

From which combination with oxide of lead, Preisser deduces the formula $C_{32} H_{15} O_{18}$ for *anhydrous quercitréin*, and represents it in its crystalline form as $2 HO, C_{32} H_{15} O_{18}$.

Bark, as quercitron is commonly called, was for many years extensively used as a yellow dye, and almost completely superseded the use of fustic, both from its beauty and its cheapness; but it has been succeeded by the salts of lead and bichromate of potassa. It is still employed to give the ground on calico for certain browns, and for dyeing green upon light muslin cloth. Goods impregnated with iron, and passed through a decoction of bark, from its containing so much tannic acid, take a beautiful olive. When used for dyeing green, the mordant is acetate of alumina; but for yellow or brown, which is now only dyed upon yarn for particular purposes, chloride of tin is employed.

When bark is used for brown upon yarns, the following, according to Napier, is the mode of procedure:—The goods are dyed a yellow by being steeped in sumach, and then passed through the chloride of tin—spirits—out of which they are wrought in a boiling decoction of bark, *raised*, that is, the color brightened by an addition of spirits. The goods are washed from this, and afterwards passed through a mixture of logwood and Brazil-wood, according to the shade of brown required. Thom of Manchester was the first to observe, that amongst the coloring principles and bases there is an elective affinity, which, if not studied, will lead to several errors. The following was communicated by him to Parnell:—

The combinations of alumina, *et cetera*, with soluble coloring bodies, seem to be cases of true chemical combination, taking place in definite proportions, and under the influence of different degrees of attractive force for coloring principles. Thus, alumina has a stronger attraction for the principle of madder than for that of logwood, and a greater affinity for the latter than for that of quercitron. When a piece of cloth impregnated with alumina is immersed in a decoction of quercitron bark, it acquires a fast yellow hue; but if it is afterwards washed for some time, and kept in a hot infusion of logwood, the alumina parts with the color from the quercitron to combine with that of logwood, and the cloth becomes changed from yellow to purple. If it be next retained for a few hours in a hot infusion of madder, the coloring principle of logwood is separated, and the alumina unites with that of madder, the tint of the cloth altering from purple to red. The amount of alumina on the fibre does not appear to diminish while these substitutions are taking place.

The same law, says Napier, is applicable when the mordant is tin; so that when goods are dyed yellow, as previously described, by quercitron, and put into a hot solution of logwood and Brazil-wood, a quantity of the yellow is displaced by the coloring matters of the latter. Should the dyer fail to strike the proper tint at the first dip, and be necessitated to continue working in the logwood and Brazil-wood, there will certainly be a deficiency of yellow from this reaction.

A vegetal extract, bearing the name of flavin, was introduced a few years ago into the art as a substitute for quercitron bark, to which, for some purposes, it is said to be superior. The general impression among dyers and calico-printers is, that it is nothing more than the coloring principle of bark, extracted for the purpose of saving the expenses of the transport of the wood. The appellation under which it was imported seems to have been arbitrarily adopted; or rather, perhaps, was so selected as to mislead the consumer into the belief that it had totally different properties than the coloring matter of the wood from which it was actually manufactured.

The mode of using it in the dye-house is to dissolve it in hot water, with which it gives a sort of turbid solution. It should be employed when newly dissolved; for, if allowed to stand, it deposits a brownish-yellow mass, in consequence of its not being completely soluble. If boiled in distilled water until all the soluble matter is taken up, and the clear solution decanted, it soon yields a subsidence.

In order to have a good color by flavin, it must first be raised by an aluminous mordant. A yellow color dyed by it weakens gradually when a little sulphuric acid has been added; and what remains preserves its brilliancy by passing through alum, and in respect of this property differs from bark.

The quantity of coloring matter in flavin, compared with bark, is as sixteen to one, or, one ounce of the extract is equal to one pound of bark. A solution of it gives the following reactions:—Sesquisalts of iron produce olive-black, and the protosalts deep greenish-black precipitates; protosalts of tin give lemon-yellow, while the persalts occasion orange-yellow subsidences; alumina causes a rich yellow deposit; acids reduce the color of the solution, and alkalies deepen it, rendering it redder.

Mr. **Leeshing** found that the action of a little acid water upon bark at a boiling beat increased the dyeing properties to a very great extent, probably by rendering the color more soluble in water, and by this means enabling the dyer to obtain a much more concentrated solution—a property of great importance in many operations, especially for the calico-printer. He also found that some of the other vegetal yellow dyes were affected in the same manner by acids, and considered the whole so important as to induce him to secure the right of the discovery by a patent, an abstract of which is appended:

In a wooden tub, or in a leaden pan, holding about eight hundred gallons, place from four to five hundred gallons of water, and one hundredweight of sulphuric acid of 1·830 specific gravity, or two hundredweight of muriatic acid of 1·192 specific gravity, and five hundredweight of the drug intended for the operation—either quercitron bark, flavin, or weld, as the case may be—in a ground or finely-divided state. After the whole has been well mixed, steam is allowed to pass through the mixture by means of a leaden pipe, reaching with the one end nearly to the bottom of the tub, the other end being connected with a steam boiler. After the temperature has been raised to 212° Fahrenheit, the boiling is continued for about three-quarters of an hour or an hour longer, when the whole is run off into a wooden trough, and mixed with a further quantity of cold water—about twice as much as has been used for the boiling. When, after cooling, the solid matter has settled to the bottom, the acid liquor is run off from the trough, and the trough filled again with water, and the whole is stirred up. After decantation, the water is again removed in the same way, and renewed once more; and after the removal of this, the remainder is generally found sufficiently free from acid. It is now either thrown upon a suitable filter, or filled into bags, and allowed to drain for a time, after which it is subjected to pressure, in order to remove as much as possible of the adhering moisture. The material so obtained is now ready to be used either directly for drying it, or it is to be dried by artificial heat, not exceeding 212° Fahr., and preserved for the same purpose.

The treatment which has just been described may be modified so as to heat or boil the dye-stuffs, mentioned in the foregoing, with weak solutions of alkalies previously to the application of acids. In this case the patentee employs for five hundredweights of the dye-stuffs intended for operation, thirty pounds of crystallized carbonate of soda, or corresponding quantities of carbonate of potassa or ammonia, or of caustic soda, or potassa, or ammonia, and four hundred gallons of water. After having boiled this mixture for a quarter of an hour, one hundred and twenty-two pounds of sulphuric acid of 1·830 specific gravity, or two hundred and forty-four pounds of hydrochloric acid of 1·192 specific gravity, are added, and the whole is boiled for three-quarters of an hour longer, when it is run off, cooled, and treated in the same way as described before. The dye-stuffs prepared according to either of these modifications are called by the patentee, when obtained from quercitron bark, *quercitrin*, when obtained from flavin, *flavetin*, and that from weld, *luteolin*. They distinguish themselves from the original drugs by being free from those constituents, such as tannin and lime, which are known to interfere with their use in dyeing; but the coloring matters contained in those drugs have at the same time undergone a change, and acquired new properties, which are exhibited by their increased affinity for mordants, and their yielding brighter and much richer shades in dyeing; and, though much less soluble in either hot or cold water, they show themselves now much better adapted for those branches of dyeing, where the temperature has to be raised to boiling, than is the case with the original drugs.

Yellows are dyed by bark in the following manner:—Work through a solution of protochloride of tin, of the specific gravity of 2° Twaddell, for thirty minutes; wash out this, and then work for fifteen minutes in a decoction of bark kept at boiling heat; lift out the goods, and add to the bark solution half-pint of single chloride of tin; work the goods twenty minutes longer in this, and wash well in cold water. This gives a rich yellow. Three pounds of bark will dye ten pounds of calico or cotton yarn.

Dark shades of yellow are dyed in the same manner; but previously to working in the spirit or protochloride of tin, the cotton is steeped for six hours in a decoction of sumach, put in while hot, and allowed to cool, proceeding afterwards exactly as in the previous case, with the same quantity of stuff.

This last yellow, as has been already intimated, forms the basis for brown. After having dyed the goods yellow, they are washed, and then wrought in a decoction of three pounds Brazil-wood and one pound logwood; after fifteen minutes' working in this, there are added four ounces alum in solution; again wrought for fifteen minutes, and washed. These proportions will produce a very rich shade of brown, and any other variety of shade may be given by varying the proportions of the ingredients, and the depth of yellow as the ground.

A decoction of bark is also used for dyeing yellow upon silk. For five pounds of silk, work for half an hour in a solution of one pound of alum in one gallon of water; then wash from this in hot water, and afterwards work the goods in a decoction of two pounds of bark—the bark must be boiled in a bag—for half an hour; then add a pint of the alum solution, work ten minutes more, wash out, and finish. Or a very deep rich yellow will be given by proceeding in the same way; but instead of adding one pint of alum as raising, add two ounces by measure of single chloride of tin; work ten minutes, wash in water, then finish through a solution of white soap. Of course, different depths of yellow may be dyed upon silk by using different quantities of the bark and strengths of the mordant.

Working cotton for a few minutes in acetate of alumina at the specific gravity of 7° Twaddell, and then through a hot decoction of bark, produces a very good rich yellow, which soon changes, however, by exposure to the air; but for dyeing greens on light cotton goods, as muslins and gauze lenos, they are first dyed yellow by this means, using about two pounds of bark for ten pounds of cloth. After being dyed yellow, they are wrought in a solution of extract of indigo, the acid of which has been previously neutralized by carbonate of soda, forming a solution of indigo termed *chemic*. The yellow-dyed goods are wrought in this till the green is of sufficient depth; the length of time will, therefore, vary according to the strength of the chemic used.

This sort of green is only suitable for such of the above-mentioned goods as are to be finished in starch, the substance which chiefly contributes to give adhesion to the dye.

SAFFLOWER; *Bastard Saffron*, *Carthamus*.—This plant is called by botanists *Carthamus tinctorius*. It is a native of Egypt, and the warmer climates of Asia. It has been cultivated in Europe, near Alsace, and also around Lyons. The Chinese have long known its use, and produce from it their finest red. The color called by them *bing*, which is used by the Japanese ladies as a cosmetic, is made from it, and is kept in little porcelain cups similar to those retailed in this country as *pink saucers*.

It is obtained mostly from the East Indies and Turkey; the former is considered the best.

The *carthamus tinctorius* is an annual plant, with an upright, firm, smooth stem, of a light grey color. It grows to about three feet in length, when it divides into several branches, bearing leaves of an oval form, and edged with small spines. Each of the branches is terminated by a large flower-head, composed of several flowerets of a deep red color. The plant is propagated by seeds, which are sown early in spring. It is from the flower that the dye or coloring matter is obtained; and experience has taught that the richest color is produced when the flowers are gathered before being fully blown. When collected, they are dried in the shade, and carefully preserved from any moisture, which would deteriorate the color. Safflower is often found injured in this manner.

The plant is still cultivated in Egypt; and, according to HASSELQUIST, as soon as the flowers are collected they are pressed between two stones, so as to deprive them of a portion of their juice; they are then washed several times with spring water, which, in Egypt, generally contains a little common salt in solution. On being taken out of the water they are pressed between the hands, and then spread out on mats upon terraces, and allowed to dry slowly, being covered by mats during the day and exposed again at night. They are turned over from time to time, and when found to be properly dried are preserved for sale.

The use of this dye, says VOLNEY, in his Travels in Egypt, is probably as old as the time of the Tyrians, and the processes are still carried on to a perfection not unworthy of that people; but the workmen, jealous of the art, keep it an impenetrable secret.

The flower, or *safflower*, as it is termed in commerce, contains two coloring matters, one of which is yellow and very soluble in water, but is not used directly as a dye in any dyeing operation, although skins and leather, when steeped in it, become tinged of a beautiful and very permanent yellow, and even the hands of those working in it contract a stain of the same color, which is not easily removed.

This yellow coloring matter is separated as much as possible from the vegetal fibre, by washing in water upon a filter of cloth, so long as the water passing through the filter is colored; but even the most careful washing does not completely free the fibre from this yellow ingredient. The Editor thinks it probable that some of this yellow coloring matter is in combination with the red, and is not decomposed by water, but is set at liberty when the red is acted upon in a manner to be afterwards described; and hence the most carefully washed safflower, when *bled*, as the dyers term it—that is, when the red is extracted—contains in its solution a great quantity of the yellow also. The composition of the flower, as imported to this country, according to DUFOUR, is as follows:—

Red coloring matter,	0·05
Yellow color, with acetate of potassa and chloride of potassium,	1·42
Extractive matter, with sulphate lime and potassa,	2·68
Yellowish-green matter,	0·55
Resin,	0·03
Wax,	0·09
Woody fibre,	4·96
Alumina and lime,	0·05
Red oxide of iron,	1·02
Sand and particle of plant,	0·46
Moisture,	0·62
	11·93

From this analysis it will be seen that the quantity of coloring matter in safflower is very small. The red extract is found to have acid properties, and has been therefore called carthamic acid; it is insoluble in pure water, but dissolves readily in water containing alkaline carbonates, from which it is again precipitated by acids; it is also soluble in alcohol, imparting to that liquid a deep red when cold, but an orange tinge when hot: it is slightly soluble in ether.

M. PREISSER has discovered that carthamic acid loses a portion of its oxygen under the action of sulphide of hydrogen, and is then converted into colorless acid, to which he gives the name of carthamous acid. An excellent method of showing these effects is to wash a quantity of safflower in water, and then dissolve the red by carbonate of soda; this alkaline liquor is next precipitated by the hydrate of lead, which forms an insoluble lake of carthamate of lead. This salt is well washed, and then subjected to the action of sulphide of hydrogen, which converts the lead into a sulphide; the whole is filtered, and the liquor thus obtained has a yellow color, which, when evaporated, yields a mass of needle-shaped crystals, which constitute carthamous acid. This acid has a slightly bitter taste, is insoluble in water, dissolves to a small extent in alcohol, and when exposed to the air assumes a yellow color. It dissolves in sulphuric acid without change of color, and in hydrochloric and nitric acid with the aid of heat. When brought into contact with oxygen, along with some alkaline body, it undergoes a remarkable modification, and suddenly acquires a yellow color, which changes to a rose tint, and dissolves in alkaline solutions, from which, by the addition of an acid, it may be precipitated as carthamic acid, having absorbed oxygen. According to the above authority, M. PREISSER, carthamous acid is composed of—

	At. Weight.	Centesimally.
52 Eqs. Carbon,	312	76·10
18 Eqs. Hydrogen,	18	4·38
5 Eqs. Oxygen,	40	19·52
1 Eq. Carthamous acid,	370	100·00

and crystallizes with two atoms of water.

The composition of carthamic acid is given as follows:—

	At. Weight.	Centesimally.
52 Eqs. Carbon,	312	70·06
18 Eqs. Hydrogen,	18	4·01
7 Eqs. Oxygen,	56	25·03
1 Eq. Carthamic acid,	376	100·00

The yellow color washed from the safflower, when evaporated to the consistence of an extract, and then acted upon by alcohol, produces a soft yellow substance, having a saline taste; and when thus purified, the color is not so soluble in water. It has a slight acid reaction. The addition of acids renders the solution nearly colorless; alcohol, on the contrary, renders it dark; sesquichloride of iron gives a very deep tint; protochloride of tin and acetate of lead give a yellow precipitate; sulphate of copper gives a yellow-green precipitate.

The safflower of commerce varies considerably in its quality, both as to the quantity and brilliancy of color it produces. No chemical method of testing its quality which could be made available in the dye-house, has yet been discovered. The only reliable process is to dye with it a given quantity of cotton, as will be described afterwards in treating of the different processes adopted by dyers for that purpose.

The safflower is found in the market in dry hard cakes. To prepare it for dyeing, a quantity of these cakes are steeped in clean cold water. Hard or spring water is preferable for this purpose. A cover is put upon the top of the cakes, and is subjected to a gentle pressure to keep them under the water. They are allowed to lie in this condition till thoroughly wet and penetrated by the water, when the cakes expand and open up, under the influence of the moisture, into fine fibres. The whole is now removed by small quantities at a time, and placed upon a fine hair sieve, when water is passed through until it ceases to be colored yellow. The washings are allowed to flow away, and the red fibres are then placed into a vessel sufficiently large to hold a gallon of water for each pound of safflower. To this water is added from three to four ounces of carbonate of potassa or soda for every pound of safflower; the whole is well stirred, and the stirring repeated every half hour. After six or seven hours the safflower has lost its red color, and acquires a dun tint; the whole is again passed through a hair sieve; but on this occasion the liquor passing through is carefully preserved, as it contains the red coloring matter forming the dye; a little clean water is poured over every sieve-charge of the exhausted fibre, to wash out all coloring matter. The fibre is then pressed as dry as possible, and thrown away. The liquor has now a brownish-red color, and is ready to dye cotton—a process which is performed as follows:—

To the liquor, or to that portion of it which the experienced dyer knows to be required for the particular tint, as much acid is put as will not only neutralize the alkali used for extracting the red, but give a considerable acidity to the taste; sulphuric acid is generally used for this purpose. The cotton is then steeped in this liquor till all the red color is taken up by the cotton, which is known by a drop of the liquor held between the eye and the light being of a yellow color. It is scarcely necessary to remark, that the cotton must be kept well spread out, and in motion during the whole of the time it remains in the solution, in order to obtain an equal dye over all its parts. The cotton is now washed in clean spring water, and then finished or dried, after immersion in cold water containing in solution some cream of tartar. The color should not be exposed to sunshine or any vapor during drying, as it is easily affected by these influences, and should be dried in the cold or in a very dry heat.

It has been seen that sulphide of hydrogen converts the red carthamic acid which constitutes the dye into a white acid. It will therefore follow, that if the air of the apartment in which the cotton or other goods dyed by this substance is dried, have in it any sulphide of hydrogen—which is a very common ingredient in dye-works—the red produced by safflower will be destroyed.

It has been stated, that notwithstanding all the care that can be given to the washing of safflower some of the yellow remains, and is found in solution amongst the red; and also that animal tissues are stained by this yellow dye. Hence, when silk or woollen has to be dyed red, if the process were conducted in the same manner as with cotton, this yellow matter would affect the beauty of the dye. To avoid this, when silk or woollen is dyed red by safflower, the following process is adopted:—The color is first taken up by the cotton, as already stated, and the cotton washed from all yellow, and then it is put into water containing a little of an alkaline carbonate, and the red dissolved off. This red solution is that used for dyeing woollen and silk, which is done in the same manner as the cotton, only, with woollen, the solution is used hot.

There has been lately introduced an extract of safflower, which is a solution of carthamic acid, or rather that coloring matter held in suspension. Instead, therefore, of preparing the safflower from the cotton, as described, woollen and silk dyers use this extract, which is done by pouring a small quantity of it into water, adding a little acid—generally a little tartaric or citric acid—and then working the fibre in it till all the red is taken up.

The mode of testing the commercial value of safflower will now be apparent, and that it can only be done comparatively; namely, by taking the different samples to be tested along with a known quality, weighing an exact quantity of each, and treating them as has been described; then dyeing with each an exact quantity of the same kind of cotton, and comparing the depth of tint obtained.

The colors dyed by safflower are very bright, but they are very fugitive, giving way by the slightest alkaline action, and also by exposure to moist air.

A deep rose color will be produced upon ten pounds of cotton by four pounds of safflower. Prepare the safflower as just detailed, only adding to the liquor produced as much water as will suffice to work this quantity of cotton; then continue to work the cotton so long as there remains any red tint in the liquor. For a light pink, two pounds safflower will suffice, and for a deep crimson seven or eight pounds will be necessary: this last color will require several hours' working.

A rich scarlet may be produced by passing the cotton first through a strong solution of annotta—see page 570—until it is a deep orange, then dyeing with seven pounds of safflower in the same manner as the crimson: this produces the finest possible scarlet upon cotton.

A good pink may be dyed upon five pounds of silk by one pound of safflower, treating it as above described for dyeing silk. By using three pounds of safflower a good rose color is produced, but for this shade the silk should be previously dyed lavender by working it for a little in archil—see page 570—and then proceeded with for rose. A deeper shade may be obtained by using more safflower and a deeper bottom of lavender. Woollens are seldom dyed with safflower.

NAPIER mentions a fact, interesting in a philosophical point of view, as to the attraction of organic fibres for coloring matters in suspension; for the red color of safflower, when the acid is added, is held merely by suspension. If a large wide vessel be taken, filled with water, having in it a little carthamic acid, and a skein of cotton be suspended in the centre of the solution, in a few hours the cotton will have attracted all the coloring matter in the water, indicating thereby a distinct power of attraction exercised by the fibre, differing from mere capillary attraction, and also that there must have been a regular circulation of fluid through the whole mass, and also through the organic fibres of the cotton—a subject deserving of a much more lengthened investigation.

SAUNDERS-WOOD—more properly termed Santal or Sandal wood—is the wood of the *pterocarpus santalinus*, a native of the East Indies, growing chiefly on the Coromandel coast. It is a solid compact wood, and is imported in large billets. On the outside it appears of a dull muddy red, nearly black; within it is a bright red, but becomes brown by exposure. It is used always in a ground state, and is easily distinguished from Brazil-wood from its hardly imparting any color to boiling water.

Santal-wood contains about 16 per cent. of coloring matter, which is all soluble in alcohol. On evaporating this solution to dryness, the color remains mixed with a little resinous matter, which is purified, according to M. PREISSER, by mixing the ethereal solution of this wood with oxide of lead, which forms a lake. The lead is afterwards separated by sulphide of hydrogen, and the santalin is obtained as a white crystalline powder by evaporation *in vacuo*. This powder, when exposed to the air, becomes red, especially if subjected to ebullition in water, or to the action of the alkalies. This red color is soluble in ether and alcohol, and, what is very singular, is also soluble in water, although in the wood it is very difficultly so.

If alcohol contains but a small portion in solution, the color is yellow, but if a large quantity, the solution is red. This solution thickens in the air like varnish. Acetic acid dissolves the color, and gives a red solution. It possesses an astringent taste, and colors the skin red.

One hundred parts of boiling oil of turpentine dissolve only 0·65 part of santalin. The same quantity of volatile oil of lavender, at the boiling point, dissolves two per cent. The aqueous solutions of potassa, soda, and ammonia dissolve it, and give it a violet-red color. The santalin may, according to M. PELLETIER, be precipitated from these solutions without change, by the addition of an acid. The liquor, however, remains yellow, but gives a blue color by reflection.

Chloride of tin throws down a purple precipitate from the alcoholic solution; the salts of lead give a violet-colored one; the chloride of mercury, a scarlet one; the sulphate of iron, a deep violet; and the nitrate of silver, a reddish-brown. The salts of alumina do not precipitate it, unless they are added in the state of solution. By distillation it yields a small quantity of empyreumatic oil. Concentrated sulphuric acid blackens it. Nitric acid decomposes it, even when cold; by its action, a yellow resinous matter, a bitter soluble matter, and oxalic acid are obtained.

Santalin is composed of—

	At. weight.	Centesimally.
16 Eqs. Carbon,	96	26·6
8 Eqs. Hydrogen,	8	2·2
32 Eqs. Oxygen,	256	71·2
1 Eq. Santalin,	360	100·0

This differs from the composition of brazilin. It also differs from Brazil-wood in its dyeing properties, both as to the particular tint and its reaction with mordants, in which properties it more resembles barwood.

The coloring matter of the wood is more soluble in water containing in solution some astringent matters. Hence practical men generally add with the wood some sumach. Its use is mostly confined to woollen dyeing.

Sooranjee—a name given to the plant called by botanists *mornida citrifolia*—has been long and familiarly known as yielding one of the most extensively employed native Indian dyes. Professor **Anderson** of the Glasgow University has given this subject a complete investigation; and the following account of this interesting substance is taken from the excellent memoir by that chemist:—

The subject of these experiments was imported into Glasgow, some time since, under the name of sooranjee, with the intention of introducing it as a substitute for madder in the art of dyeing. For this purpose it was, on its arrival, submitted for trial to some of the most experienced and skilful calico-printers in Glasgow, all of whom concurred in declaring it not to be a dye at all, and to be totally destitute of useful applications. Professor **Balfour**, happening to hear of this circumstance, was so good as to obtain a quantity of the root, which enabled the professor to submit it to a chemical investigation.

Sooranjee is the root of the plant, and is imported cut up into pieces from one to four inches in length, and varying in diameter from half, down to nearly an eighth of an inch. On the small pieces the bark is thick, and forms a large proportion of the whole root, but on the larger fragments it is much thinner. Its external color is pale greyish-brown; but when broken across, it presents colors varying from fine yellow to brownish-red, and confined principally to the bark. The wood itself has only a slight yellowish shade, deepest in the centre, and scarcely apparent close to the bark; but it is colored dark-red by alkalies, indicating the presence of a certain quantity of coloring matter in it. The bark is readily detached, and its inner surface, as well as that of the wood, has a peculiar silvery appearance, most apparent on the large pieces, and almost entirely absent in the smaller. Boiled with water, it gives a wine-yellow decoction, and with alcohol a deep red tincture.

Morindin.—For the preparation of the coloring matter of sooranjee, to which he gave the name of *morindin*, Dr. **Anderson** at first attempted the use of boiling water, in which his preliminary experiments had shown it to be pretty soluble; he found, however, that this method was inapplicable, as the decoction contains a quantity of mucilaginous matter, which hinders the filtration of the fluid. The use of alkalies, in which the coloring matter is rapidly dissolved, likewise proved abortive, and recourse was finally had to alcohol, which succeeded perfectly. The bark of the root, separated from the woody portions and ground to fine powder, was boiled with six times its weight of rectified spirit, and the tincture filtered boiling hot. Its color was deep brownish-red, and on cooling it let fall the greater quantity of the coloring matter as a brown flocculent precipitate, containing the morindin, contaminated by another red coloring matter which exists in the root in small quantity only. A second decoction, with an equal quantity of spirit, gave a paler solution, from which morindin was deposited with a much smaller quantity of the red coloring matter. This treatment was repeated over and over again, as long as the tincture deposited anything on cooling; and every successive boiling produced it purer than the preceding, until at length, from the final decoctions, it made its appearance in the form of minute radiated crystals of a yellow color. By successive crystallizations from alcohol of 50 per cent., the red matter with which it was mixed was entirely removed, and the morindin obtained of a fine yellow color. It was still, however, impure, and contained a quantity of ash, amounting in one experiment to 0·47, in another to 0·32 per cent. The separation of this could not be effected by crystallizations from alcohol alone; but, after some trouble, it was completely removed by solution in alcohol slightly acidulated by hydrochloric acid, from which it crystallized in a state of purity.

Morindin is deposited from alcohol in minute needles, which, if the solution be dilute, make their appearance in radiated circles attached to the glass, and resembling in their arrangement the crystals of wavellite. They are extremely soft, and on being detached, collected on a filter and dried, mat together into a mass, presenting a rich sulphur-yellow color and satiny lustre. These crystals are sparingly soluble in cold alcohol, much more so in boiling spirit, especially if dilute; and the fluid on cooling is filled with a mass of bulky needles, which when dried shrink into a very small bulk. They are much less soluble in absolute alcohol, and totally insoluble in ether. Water dissolves morindin in the cold very slightly, although sufficiently to communicate a yellow color to the fluid; at the boiling temperature, however, it is readily taken up, and again deposited on cooling as a gelatinous mass, destitute of all traces of crystallization, which stops up the pores of the filter, and prevents the separation of the mother-liquor. It dissolves in solutions of the alkalies with a fine orange-red color. With concentrated sulphuric acid it gives a deep purple, which is violet in thin layers. After twenty-four hours' contact, the solution, on being diluted, deposited yellow flocks of the coloring matter in an altered condition, as it was now totally insoluble in cold water, and gave with ammonia a violet and not an orange solution. Nitric acid, specific gravity 1·38, dissolves morindin slowly in the cold with a deep brownish-red color. The application of heat immediately produces violent action, the brown color disappears, and nitrous acid fumes are evolved. The fluid, after long-continued boiling with the acid and neutralization with ammonia, gave no precipitate with salts of lime.

Solution of morindin gives, with subacetate of lead, a precipitate, depositing itself in crimson flocks, which are extremely unstable, and cannot be washed without losing coloring matter. With solutions of baryta, strontia, and lime, it gives bulky red precipitates, sparingly soluble in water. Sesquichloride of iron produces a dark-brown color, but no precipitate. When its ammoniacal solution is added to that of alum, the alumina precipitated carries down with it the morindin as a reddish lake; and when added to sesquichloride of iron, a brown precipitate is thrown down, which cannot be distinguished from pure sesquioxide of iron, but which contains morindin, as the supernatant fluid is colorless.

From analyses of morindin, the results were as follow:—

	At. Weight.	Centesimally.		
		Theory.	Anderson.	
28 Eqs. Carbon, ...	168 ..	55·44 ..	55·46 ..	55·40
15 Eqs. Hydrogen, ...	15 ..	4·95 ..	5·19 ..	5·03
15 Eqs. Oxygen, ...	120 ..	39·61 ..	39·35 ..	39·57
1 Eq. Morindin, ...	303 ..	100·00 ..	100·00 ..	100·00

The formula thus ascertained brings out an interesting relation between morindin and the coloring matters of madder, and more especially that one which is obtained by the sublimation of madder-purple. From his analysis of this substance, Schiel deduces the formula $C_7 H_4 O_4$. As this, however, is no more than the simplest expression of the analytical results, and as all the other madder coloring matters examined contain twenty-eight equivalents of carbon, one is justified in supposing its real constitution to be represented by quadruple of that formula, or $H_{28} H_{16} O_{16}$, which differs from that of morindin by a single equivalent of water only. The unsublimed madder-purple is also connected, though more remotely, with morindin, and differs only by containing five equivalents of hydrogen less, its formula according to Schiel being $C_{28} H_{10} O_{15}$.

This similarity, however, does not extend itself to their properties as dyes, in which respect they differ in a very remarkable manner. It has been already mentioned that the calico-printers had entirely failed in producing a color by means of sooranjee; and this Dr. Anderson fully confirmed as regards the common mordants. He digested morindin for a long time, in a gradually increasing heat, with small pieces of cloth mordanted with alumina and iron; but nothing attached itself, and the mordants, after boiling for a minute or two with soap, were found to be unchanged. Even with the root itself, alum mordant only acquired a slight reddish-grey shade, and iron became scarcely appreciably darker in color. The case was different, however, when cloth mordanted for Turkey-red was employed. Pieces of calico prepared for Turkey-red both by the old and new processes were obtained; and it was found that both acquired with morindin, in the course of a couple of hours, or even less, a dark brownish-red color, devoid of beauty, but perfectly fixed. These observations agree with the account given by Mr. Hunter of the method of dyeing with the *M. citrifolia* employed by the Hindoos. The cloth is first soaked in an imperfect soap, made by mixing the oil of the *Sesamum orientale* with soda-lie. After rinsing and drying, it is treated with an infusion of myrobalans—the astringent fruit of the *Terminalia chebula*—and exposed for four or five days in the sun. It is then steeped in solution of alum, squeezed, and again exposed for four or five days. On the other hand, the powdered roots of the *Morinda* are well rubbed with oil of sesamum, and mixed with the flowers of the *Lythrum fruticosum*—Roxburgh—or a corresponding quantity of *purwas*—the nut-gall of a species of *Mimosa.*—The whole is introduced along with the cotton into a large quantity of water, and kept over a gentle fire for three hours, when the temperature is brought to the boiling point. The red color so obtained is, according to Mr. Hunter, more prized for its durability than its beauty. This is simply a rude process of Turkey-red dyeing. He also mentions that, by means of iron mordant, a lasting purple or chocolate is obtained; but in this case the color is probably affected by the tannin of the astringent matters employed in the process.

Morindin is a true coloring matter, and is capable of attaching itself to common mordants. It gives with alumina a deep rose-red, and with iron violet and black; but the colors are not very stable, and it has a strong tendency to attach itself to the unmordanted parts of the cloth, and to degrade the white. Morindin, after treatment with sulphuric acid, is capable of attaching itself to ordinary mordants.

The discovery of a peculiar coloring matter, capable of fixing itself exclusively on Turkey-red mordant, is of interest, as establishing the existence of a peculiar class of dyes hitherto totally unsuspected, a class which may be extensive, and may yield important substances. It may serve also, in some respects, to clear up the *rationale* of the process of Turkey-red dyeing, which has long been a sort of opprobrium of chemistry. Although that process has been practised for a century in Europe, and has undergone a variety of improvements, no clear explanation of it was for a long time given; but it was supposed that, by the action of the dung, of which large quantities are employed, the cloth underwent a species of *animalisation*, as it was called, by which it acquired the property of receiving a finer and more brilliant color than could be attached to it by purely mineral mordants. Recent experiments have, however, shown that the oil, which is largely employed in the process, undergoes decomposition by long exposure to the air in contact with decomposing animal matter, and is converted into a sort of resinous matter, which constitutes the real mordant for Turkey-red. This has been pretty clearly made out by the experiments of Weissgerber. He found that when cloth had been treated with oil, so as to give when dyed a fine rose-red color, he could, by digestion with acetone, extract from it the altered oil; and as it was removed, the cloth gradually lost the power of attracting the coloring matter of madder, until, when it was entirely separated, the cloth passed through the dye without acquiring any color. On the other hand, he found that, by applying the substance extracted by acetone in sufficient quantity to cloth, he could obtain the richest and deepest colors with madder, without the addition of any other substance whatsoever. These observations receive additional confirmation from the experiments detailed in the present paper, as it must be sufficiently obvious that the dark-red color obtained on Turkey-red mordant with morindin, must be entirely irrespective of the alumina, on which that substance is incapable of fixing.

Dr. Anderson fully agrees with the opinion expressed by Persoz, that the use of alum mordant, which is at present always employed in Turkey-red dyeing, will be entirely abandoned so soon as calico-printers have learned the method of modifying at will the oil which they employ, so as to bring it at once into the state in which it acts as a mordant. Some steps have been made in this direction by making use of some chemical agents, as nitric acid and chloroxide of calcium, for the purpose of acting on the oil, but the improvements which have been effected stop far short of what will eventually be effected, when the system of pure empiricism, which has been all along employed in this particular process of dyeing, is abandoned, and the subject submitted to really scientific investigation. It is understood that M. CHEVREUL has entered upon the inquiry, and in his hands there is little doubt but that it will meet with a satisfactory solution.—*Transactions of the Royal Society of Edinburgh.*

SUMACH—*Rhus coriaria.*—This has been already referred to under FUSTET. It was long known as *young fustic,* and is still occasionally so named, from some kinds of it producing a yellow dye with aluminous and tin mordants, especially upon woollen fabrics. It is now seldom used directly as a dye, but is extensively employed as an auxiliary, in consequence of its containing large quantities of tannin and gallic acid; and has in many operations superseded the use of galls. There is considerable variety in the qualities of the sumach brought into this country, and the different kinds are distinguished by the names of the countries from which they are imported, such as Sicily sumach, Malaga sumach, *et cetera.* Each has qualities rendering it more suitable for certain uses than another. Sicily sumach has a fine greenish-yellow color, and is admirably suited for bright shades of red with Brazil wood. Malaga sumach has more of a fawn tint, and suits for deep colors, as black, brown, *et cetera.* So great is the difference between different sumachs, that, in some cases, it would require nearly fifty per cent. more of one than the other to produce the same effects. Decoctions of sumach should be used when newly made. If allowed to stand a few hours after cooling, fermentation begins in the solution. In this case, the yellow coloring matter is immediately destroyed, the tannin is converted into gallic acid, the decoction loses much of its dyeing property, and colors dyed with it in this state are neither so rich and deep, nor so permanent, as if dyed previous to fermentation commencing. Goods are often allowed to steep in the sumach until fermentation has proceeded to such an extent that the solution has a sirupy appearance, and is quite sour to the taste. This practice is reprehensible, producing a bad effect upon the colors afterwards dyed upon the goods.

As already stated, sumach is used principally as a base or bottom for giving depth or solidity to the colors. This will appear from the following details of the reactions in dyeing a black upon cotton:—The goods are immersed in a decoction of sumach at a boiling heat, and allowed to steep till cold. They are then lifted out, when they appear of a hazel color; after which they are passed through lime-water. This produces a deep green, which is very fugitive. From the lime-water they are removed direct to a solution of copperas, or iron liquor, the former being most generally used. This gives a deep heavy slate color, bordering on black. After washing from this, to remove any iron not combined with the color, the goods are then wrought in a decoction of logwood, which produces the rich black. Without the tannin of the sumach, the iron and logwood could not give a black of any degree of permanency.

If red is to be dyed, the goods from the sumach are steeped in a solution of chloride of tin; this produces, with the sumach, a rich yellow. After washing from the tin solution, the goods are wrought in a decoction of Brazil wood, which gives a rich red; but without the tannin of the sumach, the color produced by the tin and Brazil wood would be a very poor and fugitive red. As gallic acid is known not to have the same effect as tannin in producing these results, it will follow, if the tannin in the sumach is converted into gallic acid, by fermentation, the effects of the sumach will thus be destroyed to that extent to which tannin differs from gallic acid.

From these preliminary observations, practical readers will see the value of such investigations. The following is taken from an article by M. BARRESWEL, in the *Comptes Rendus:—*

When solutions of gallic or of tannic acid, which are colorless, and generally form colorless salts, or of the color of the bases, are poured into a solution of the sesquisulphate of iron, an intense blue precipitate is formed, which remains suspended in the liquid. This anomalous fact has frequently excited the attention of chemists, MM. BERZELIUS and CHEVREUL have even expressed some doubts respecting the simplicity of the reaction.

It has long been known that tannic and gallic acids do not precipitate the protosalts of iron when protected from contact with the atmosphere. BERZELIUS, CHEVREUL, and PERSOZ have, moreover, observed that when gallic acid or tannin is conveyed into a salt of the sesquioxide of iron, it is always reduced to the state of a protosalt. This fact is easily proved by adding to the blue solution produced by the sesquisulphate of iron in a solution of gallic acid, an excess of acetate of lead or of carbonate of lime, which precipitates the blue combination, and at the same time the sulphuric acid. A colorless liquid is separated by filtration, in which the presence of iron may be demonstrated in the state of protoxide.

These experiments are insufficient to explain this curious reaction. It is not improbable to admit, as MM. BERZELIUS and CHEVREUL have done *à priori,* that the oxygen combining with the gallic acid or the tannin converts them into a new acid of a blue color; but positive experiments were wanting to decide the point.

When a solution of tannin or of gallic acid is poured by drops into a solution of sesquisulphate of iron in excess, no blue coloring is obtained; if there is one produced, it is only momentary. Nor is there one formed with the same salt in minimum in presence of chlorine, nor with a protosalt of iron and gallic acid oxidized in various degrees by chlorine, by a salt of silver, or lastly, by the atmosphere in an alkaline solution.

When a solution of gallic acid in excess is conveyed into sesquisulphate of iron, and the liquid thrown down by acetate of lead, a blue paste is obtained, which, treated with oxalic acid, forms soluble oxalate of iron; the blue color disappears entirely, and is restored by acetate of soda. The solution of the oxalate, diluted very much with water, treated cautiously with ferrocyanide and ferricyanide of potassium and sulphide of hydrogen, presents all the characters of the salts of iron in the state of sesquioxide and protoxide.

It appears that the conclusion to be drawn from the above facts is, that if one starts with a protosalt of iron, it is requisite to add oxygen, and if sesquisalt be commenced with, some oxygen must be removed, in order to produce the blue compound, and that this compound contains the two oxides. In the first case, the protoxide of iron combines with the oxygen of the atmosphere; in the second, a portion of the oxygen of the sesquioxide destroys a corresponding portion of the gallic acid or of the tannin, converting it into a brown substance. This substance does not enter into the constitution of the new compound, which must be considered as a salt formed of tannin or gallic acid, and of an intermediate oxide of iron, probably of a blue color, the tint of which is slightly altered by this brown substance.

To prove, in the most evident manner, that the blue coloring is not to be ascribed to a blue acid, but to a particular oxide, BARRESWEL endeavored to obtain other blue salts with mineral acids—for instance, with sulphuric acid. For this purpose he prepared some mixtures, in variable proportions, of the protosulphate of iron and of the sesquisulphate, and to avoid an inevitable separation of the two salts from their different degrees of solubility, he removed *immediately* the water by adding to the solution concentrated sulphuric acid in large excess, taking care to produce as little heat as possible. In this manner a thick paste of a *deep blue* was obtained, the tint of which was more or less pure according to the proportions of the two salts of iron. He likewise produced a blue sulphate, but of very ephemerous existence, by evaporating rapidly a mixture of the two salts of iron; the blue tint appeared at the moment when the mass was nearly dry. On substituting phosphate of soda for the sulphuric acid, he obtained a deep-blue phosphate of iron and some sulphate of soda, which removed the water immediately. An endeavor was made, but without success, to prepare combinations with other salts. The hyposulphate of soda alone afforded an intense blue coloring, but of remarkable instability. This is not surprising; there are many instances in chemistry of bases which prefer combining with certain acids and refuse to unite with others; such, for instance, among others is the protoxide of copper.

The same chemist made numerous experiments to obtain the blue oxide in a free state, and succeeded several times, but under circumstances which he was not able to produce at will. It is, however, a well-known fact, that when a protosalt of iron is precipitated with ammonia in contact with the atmosphere, the white precipitate of the protoxide soon becomes green, passing first, however, through blue.

The impossibility of obtaining the blue sulphate of iron in a crystalline state, and of isolating the acid of the blue gallate compound, prevented BARRESWEL from having recourse to analysis in order to arrive at the formula for these intermediate salts. He was forced to proceed by synthesis, which he confesses is far from being accurate, and it was with some doubts that he published the results.

Of all the mixtures of protosulphate and persulphate which BARRESWEL experimented on, that which afforded the most pure blue with sulphuric and gallic acids, and with the phosphate of soda, contained precisely three equivalents of protosalt to two of the sesquisalt—proportions which correspond to the cyanide $Fe_7\ O_9$, prussian blue.

If he has thus rendered probable the existence of two intermediate oxides of iron, capable of forming salts, and of entering into the salts with their peculiar color, he will have thrown some light on the various tints produced by the different kinds of astringent substances, morphin, salicylic acid, and some other organic principles; and, likewise, on the production of violet-black, brown, and green tints, with red and yellow-coloring principles, in presence of salts of sesquioxide of iron. He convinced himself that all the yellow-coloring substances—for instance curcuma—do not produce green; that the red-coloring principles—among others aloetic acid—do not give a violet; and that when there is a production of green—as with the Persian berries and the quercitron—or of violet—as with madder, logwood, *et cetera*—the phenomena are identical with those which occur with tannin and gallic acid. These observations agree, moreover, perfectly with the suppositions of M. THENARD, with the facts published by M. KÖCHLIN-SCHOUCH, and by M. SCHLUMBERGER, and which M. STACKLER has found confirmed in his establishment, that the iron mordants should be at a fixed degree of oxidation to produce beautiful dyes.

Since this paper was given to the world, some of these views have been corroborated. The paper of Professor CALVERT upon this subject is so much to the point, and its practical bearing so important, that the Editor quotes it entire:—

PERSOZ, in his *Traité de l'impression des Tissus*—Vol. I., page 262—remarks, that it is desirable, as much for the interest of the manufacturer as for that of science, that it should be known positively whether it is gallic or tannic acid which plays the most important part in dyeing with gall-nuts. This statement of PERSOZ, together with the knowledge of the fact that the manufacturers of extracts of coloring matters, were prevented from preparing extracts of tannin masses, by the rapid change which these extracts undergo, induced the author to make the following researches, with the hope of throwing some light on the subject.

The first experiments were made with the view of ascertaining the action of gallic and tannic acids in the dyebeck. For this purpose, CALVERT dipped one hundred square inches of iron-mordanted cloth into baths composed of twenty grains of these acids, and one and a half pint of water; and the dyeing was allowed to go on in the cold for twenty-four hours. It was found that the gallic acid rapidly dyed the iron mordant, but the color soon disappeared, whilst with the tannic acid, although the black was slower in forming, it remained permanent. Similar trials were then repeated, but gradually raising the temperature of the bath during one and three quarter hours to 180° Fahr., and then for half an hour to 212°. The general results were similar, the only difference being, that the black at first formed with the gallic acid, more rapidly and completely disappeared than in the experiments done at natural temperature.

These facts led to the belief that the gallic acid acted as a reducing agent on the hydrate of sesquioxide of iron fixed in the cloth as a mordant. To substantiate this view, CALVERT took a portion of the liquor from the bath in which the dyeing process had been conducted, and on examination found it to contain a large quantity of protoxide of iron in solution; whilst, in the case of the tannic acid liquor, no reduction of the oxide of iron had taken place. He also added a small quantity of chloroxide of calcium to the above solution of gallate of protoxide of iron, which not only precipitated a certain quantity of the black gallate of iron, but the liquor gave a permanent black on a fresh piece of iron-mordanted calico, leaving no doubt that the chloroxide had maintained the iron of the mordant in the state of sesquioxide. A very important question now presented itself, namely, will the presence of a free acid increase the reducing power of gallic acid? To determine this point, a weak solution of persulphate of iron was mixed with some gallic acid, and it was found that in proportion to the excess of acid, so did the blue precipitate first formed rapidly disappear, leaving in the glass vessel a brown-tinted liquor, containing a salt of proto and sesquioxide of iron. It was also ascertained that the addition of a small quantity of weak hydrochloric, sulphuric, or oxalic acid, greatly increased the reducing action. If, on the contrary, an excess of pure hydrate of sesquioxide of iron was added to a solution of gallic acid, even after several days, the dark-blue precipitate at first produced remained permanent, and no protoxide of iron was produced in the solution. If heat, however, was applied to the mixture, protoxide of iron might be detected in the liquor.

These facts clearly show, that gallic acid cannot be employed as a dye when used in excess, or in presence of any other acid; whilst tannic acid placed in similar circumstances to the above described with gallic acid, does not reduce the sesquioxide of iron, either at natural temperatures, or under the influence of heat. The only circumstances in which the conversion of the hydrate of sesquioxide of iron into protoxide was remarked, were on the addition of large excesses of hydrochloric, sulphuric, or oxalic acids. CALVERT is inclined, therefore, to believe that, under the influence of a great excess of mineral acid, the tannic acid splits up into sugar and gallic acid, and the latter substance produces the reducing effect above described. These results seem to afford an explanation of the fact observed some years ago by M. J. GIRARDIN of Rouen, that, to obtain good blacks, a calcareous water is advantageous, a result which is probably due to the lime of the carbonate neutralizing the gallic acid existing in the tanning matter, and so preventing it from exerting its reducing action on the iron mordant, which would interfere with the dyeing properties of its tannic acid.

Professor CALVERT was also anxious to ascertain the difference of the action of gallic and tannic acids on alumina. He accordingly took two pieces of calico, of one hundred square inches each, previously mordanted with alumina, aged and dunged, and placed them in separate baths, one of which contained twenty grains of gallic acid, and the other twenty grains of tannic acid; and during two and a quarter hours gradually carried the whole to the boiling point. These pieces were then taken out, washed in distilled water, and subsequently dyed with madder. It was found that the piece which had been in the gallic acid bath was almost colorless, while that from the tannic acid had acquired a deep red tint. The same results were obtained on dyeing a piece of calico, mordanted with alumina, in a bath composed of thirty fluid ounces water, twelve grains peachwood, and eight grains garancin, together with twenty grains tannic, or twenty grains of gallic acid. To leave no doubt as to the true action of these acids on alumina, pure hydrate of alumina was introduced into two tubes, with a solution of each of them; and after a few days' contact, it was found, on examining the supernatant fluids, that the gallic acid alone had dissolved alumina, the tannic acid not having acted at all, so that the latter may be considered, if not a neutral substance, at all events a very feeble acid.

CALVERT also attempted to obtain reds and blacks with an extract of sumach which had been kept some time, but failed, owing no doubt to the transformation of its tannin into gallic acid, as the results obtained were identical to those furnished by the above free acids. This rapid transformation of tannin into gallic acid in the extract of sumach is remarkable, when it is remembered that it takes only a few weeks or months in the case of the extract, whilst it requires years when the tannin is confined in the plant. These differences are no doubt due to the presence of water, which facilitates chemical actions. This rapid deterioration of tanning matters in the form of extract, is the reason why their substitution for the solid substances themselves has not been adopted by the silk dyers or tanners. It was therefore deemed advisable to make a series of experiments, in the hope of discovering a substance which would act as an antiseptic to this peculiar fermentation, for the researches of Messrs. DELAROQUE and ROBIQUET, junior, have clearly shown that tannin is transformed into gallic acid and a substance resembling sugar, under the influence of a peculiar ferment called pectase.

CALVERT'S investigations led him to discover three substances which possess the property of preserving from fermentation tanning extracts having a specific gravity 1·250, and as, doubtless, the employment of these substances will facilitate manufactures and cheapen production, he does not hesitate to publish them. They are chloride of lime, bichloride of mercury, but especially carbolic acid; and to show the efficiency of this acid, it may be added, that an extract of *sumach*, which was mixed with a few per cent. of this acid, was perfectly sound twelve months after being mixed. The first two substances answer very well, but the last has the great advantage of not interfering with the general applications of the extract of tanning matters.

The remarkable power of dissolving the hydrates of oxides of iron and aluminum possessed by gallic acid, induced Professor CALVERT to try its action, as well as that of tannic, on metallic iron. For this purpose, one thousand grains water, twenty-five grains acid, and one hundred grains iron-wire were introduced into tubes, so arranged as to convey the gases evolved to the pneumatic trough, care being taken to exclude all air. After a few days, it was found that several cubic inches of gas had been given off from the gallic acid tube, which, on testing, proved to be nearly pure hydrogen, whilst the liquor remained colorless, and only assumed a slight blackish-blue tint when exposed to the air. The iron, on being taken out, was carefully dried and weighed, and found to have lost 1·4 grains. Therefore, gallic acid has the property of dissolving iron. It was also observed, that in the case of the tannic acid, no gas was evolved, neither was iron dissolved; although the solution had assumed a slight purple tinge, which was attributed to some trace of oxide produced on the bright surface of the wire during its weighing. A similar series of experiments was also tried, substituting for the one thousand grains water, one thousand grains of a solution of sugar, having a specific gravity of 1·090; and it was observed, that although gallic acid acted in the way above described, tannic acid on the contrary, under the influence of the sugar, attacked the iron and gave a bulky dirty purple precipitate. Professor CALVERT regrets that he had not time to examine the nature of this action, neither the peculiar compound formed by the oxidation of the gallic acid, when brought in contact with an acid persalt of iron; but he proposes, when circumstances permit, to return to this subject.

In conclusion, from the facts contained in this paper, there can be no doubt that tannic acid is the constituent of tanning substances which produce blacks with iron mordants. 2. That the reason why gallic acid produces no black dye is, that it reduces the sesquioxide of iron of the mordant, forming a colorless and soluble gallate of protoxide of iron. 3. That gallic acid has the property of dissolving hydrate of alumina, and also of separating alumina mordant from the cloth on which it is fixed. 4. That the reason why extracts of tanning matters lose their dyeing properties is, that the tannin is transformed into gallic acid. 5. That gallic acid possesses the property of dissolving iron, and thus lays claim to the character of a true acid, whilst tannin, not having this action, appears to be in reality a neutral substance. 6. That carbolic acid possesses the property of preventing the tannin fermentation, or the conversion of tannin into gallic acid and sugar, or a similar substance, under the influence of a peculiar ferment called pectase.—*Edinburgh New Philosophical Journal.*

Allied to sumach are several other vegetal matters that contain tannin, and have been from time to time introduced into the dye-house as substitutes for sumach. Among these are the *Valonia nuts*, as the cups of the acorn from the Valonia oak are termed; they are imported in great quantity, but are inferior to sumach for the general purposes of the dye-house. For some objects, however, especially for dyeing a deep rich and permanent black upon silk for hats, the Valonia nut is in great use.

Divi divi, or *libi davi*, is another vegetal that has been tried instead of sumach, but not with success, being but poor in tannin.

Myrobalans—the fruit of a tree which grows in India, and is much used by the Hindoos as a substitute for galls—has been imported into this country for a similar object; but although it contains much of the properties of galls and sumach, and is occasionally used in their stead, it has not yet succeeded in superseding sumach.

There are many other vegetal substances that contain tannin, and which may be used in virtue of that property, and many of them have some distinctive and characteristic qualities of a different kind, which may render them useful for some particular purposes; but for general use in dyeing, nothing has yet been found capable of superseding sumach.

TURMERIC.—Turmeric, or Indian saffron, is a yellow dye obtained from the roots of *Curcuma longa.* This plant is indigenous to the East Indies and other parts of Asia, and to Madagascar. It has been cultivated with some success in Tobago, and samples from that island have been found superior to that usually imported from India. Our supplies are brought from the East Indies, China, and Java; of these, the Chinese turmeric is the best.

The roots of the *curcuma longa* spread far into the ground; they are long and succulent, and about half an inch in thickness. These roots are externally of a color inclining to grey, but internally of a deep yellow color; they are reduced to powder previous to being employed as a dye. The composition of this root, according to JOHN, is in one hundred parts:—

Yellowish volatile oil,	1
Yellowish brown resin,	10 to 11
Brown extractive matter with dyeing properties,	11 to 12
Gummy matter,	14
Matter soluble in alkalies, including earthy salts,	57
Moisture, loss, &c.,	7 to 5
	100

Cold water dissolves a little coloring matter of a yellowish tint; hot water takes up a larger quantity; but the whole coloring matter of this dye does not seem soluble in water.

Alcohol becomes yellow, and dissolves, besides the color, much of the resinous matter. Sulphuric, nitric, and hydrochloric acids, in their concentrated state, give the alcoholic solution of this matter a crimson-red color; nitrate of lead, a clear yellow; chloride of tin, yellow; salts of iron, a brown color, but no precipitate.

The coloring principle of the curcuma is obtained by macerating the powdered root in boiling water, until the liquid ceases to acquire any further tint. The residue is then to be boiled in alcohol. The greater part of the coloring matter is thus dissolved, but it is impossible to extract it completely, and the curcuma powder always remains more or less colored.

The filtered solution has a reddish-brown shade; it furnishes, by evaporation, a brown mass, which contains some extractive matters, and traces of chloride of calcium. These latter substances are left behind on treating the residue with ether, the coloring principle alone being dissolved, which may be obtained in a solid form by evaporation. The matter thus obtained is not, however, pure; to free it of all admixture, it must be dissolved anew in alcohol, and subsequently acted on by an alcoholic solution of acetate of lead. There is immediately formed a red precipitate, composed of the coloring matter, and of protoxide of lead. This deposit, having been washed and dried, is to be freely diluted with water, through which a current of sulphide of hydrogen should be passed, until all the lead becomes precipitated. The powder is now to be carefully washed, dried, and treated with boiling ether, which dissolves the curcumin, and leaves behind the sulphide of lead.

On slowly evaporating the ether, the curcumin is deposited in thin, transparent, and inodorous layers. When reduced to a fine powder, it is of a rich yellow color; indeed, the finer the powder, the brighter is found to be its tint. When in thin layers, it appears of a cinnamon-red; viewed against the light, it presents a deep red aspect.

By this proceeding, about half an ounce of curcumin is obtained from the pound of the root. By exposing it to the rays of the sun, it quickly loses its intense color, and gradually becomes of a yellowish-white.

The mean calculation of four analyses of curcumin, prepared in the foregoing manner, gave—

Carbon,	69·5
Hydrogen,	7·4
Oxygen,	23·1
	100·0

The dilute acids do not dissolve curcumin, but concentrated acids possess this property.

As might be anticipated from the above chemical reactions, and especially the effects of air upon the coloring matter of turmeric, the dye produced by this substance is very fugitive; it fades rapidly in the air; and, there being no proper mordant for it, its use as a dye must be very limited. Indeed, it is not now used except as a *topping*, to finish up and give a certain tint, which, however, only serves the emergency, and is not permanent. The rapid action of alkaline matters upon it, makes it a useful reagent for testing the presence of alkaline matters in solutions. Paper dyed yellow by turmeric, and preserved in the dark, will be rendered brown by the slightest alkalinity in water, and is, therefore, used for this purpose, under the name of test-paper.

Weld or **Wold** is a biennial plant, called by botanists, *Reseda luteola*. This plant is well known throughout Europe, and is indigenous to England; it is found growing wild in many parts of the country, and is also cultivated for its coloring produce in several counties of England, such as Kent, Herefordshire, and near Doncaster, in Yorkshire. It is very extensively cultivated around Paris, and in other parts of France. The plant, after being gathered, is carefully dried, and tied up in bundles, in which state it is sold to the dyer. When boiled, it gives out its color easily to water, producing a beautiful greenish-yellow hue, and giving the following reactions with reagents:—

Alkalies	change it to golden-yellow.
Acids	deepen the color, rendering the solution muddy.
Alum	a yellow precipitate.
Tin salts	a yellow precipitate.
Acetate of lead	a yellow precipitate.
Sulphate of iron	olive color.
Chlorine	brightens the color.
Acetate of copper	greenish-red.

The solution has a peculiar odor and a sweetish-bitter taste, and slightly reddens litmus paper.

The coloring matter of this vegetal has been called *Luteolein*, and has been examined by M. Chevreul and M. Preisser. It may be obtained in needle-shaped crystals by sublimation, but the latter chemist obtained it by making a strong decoction of the weld, which was of a clear yellow color, and deposited on cooling a multitude of small flakes of a yellowish-white tint.

If this liquid be boiled in a small quantity of chromic acid, on cooling, a large quantity of flakes of a golden-yellow color, similar to iodide of lead, that brighten by keeping for a short time in contact with air, are produced: this yellow matter is luteolein; it is presented first as white scales, and is soluble in water—more so in hot than cold—also in alcohol and ether; it has a sweetish taste, leaving a bitterness behind; it is volatile; its reaction upon litmus paper is decidedly acid.

Sulphuric acid dissolves it, producing a clear-colored solution; nitric acid, cold, acts in the same manner, but if heated, it is decomposed.

Sulphate of iron gives a precipitate of a greenish-yellow tint, which darkens by the air to an olive-brown; acetate of lead gives a white precipitate, which turns yellow by exposure.

Caustic alkalies give a deep yellow color to the solution at first, but afterwards the color is all deposited as a yellow precipitate. Baryta, strontia, and lime behave in the same way. Weld also contains tannin, which causes a change in the solution when it is allowed to stand exposed to the air.

The chemical properties of this dye have some resemblance to those of quercitrin; but it differs much from that substance in its dyeing qualities. It is used as a species of fermenting agent in certain kinds of blue vats, for the deoxidizing of the indigo or woad. It is seldom used for dyeing of cotton; and although, with an alum mordant, it gives a very fine yellow on that fabric, the yellow is very fugitive, giving way rapidly in the air. It is used, however, for dyeing yellows upon silk, to which it gives a yellow of a very fine tint.

The following process with the quantities mentioned will produce a rich yellow upon five pounds of silk:—Work the silk for an hour in a solution of alum of the strength of one pound to the gallon of water; wash from this in warm water; boil two pounds of weld for an hour in as much water as will serve to work the silk in easily; strain the liquor through a fine hair sieve; then work the silk in it for half an hour; add one pint of the alum solution; return the silk and work ten minutes longer, and wash out. Different depths of yellow can be dyed by varying the quantity of weld; and by adding to the weld a small quantity of a solution of annotta, amber and straw tints are produced.

Woad—*Isatis sativa*—is a plant known and used for the purposes of dyeing from the earliest time. The ancient Britons, when invaded by the Romans, are described as having their bodies stained with the colorous matter of this plant. It is cultivated in the Azores and the Canary Islands, in Italy, in Switzerland, in parts of Germany, Sweden, and in various districts of France. It is likewise indigenous to England, and is still cultivated in Lancashire. For many centuries it was a most important branch of British industry, as has been repeatedly referred to both in the historical remarks and elsewhere. It is still used as a dye for blue in woollen and silk stuffs, often, however, accompanied with indigo, the coloring matters of these substances being similar. A superior quality of this dye, which is principally produced in the South of France, is known in commerce by the name of *Pastel.* The *Isatis sativa* is a biennial plant, having a large woody root, which penetrates deep into the ground; the stem is from three to four feet high, and about half an inch thick, divided into several branches, which are loaded with many leaves of a lurid green color. Three or four crops are usually obtained in one year. The plants are mowed with a scythe, and, as soon as collected, are washed in a stream of water and dried in the sun. This must be rapidly done, otherwise the woad will be impaired in quality. When dried, it is conveyed to a mill and ground into a smooth paste, which is laid in heaps, pressed close together, and covered to protect them from rain. If any crack appear in these heaps, care is taken to unite them, as that would also impair the quality of the woad. After remaining for a fortnight in heaps, the whole is rubbed together and formed into solid balls, which are pressed into a compact substance in wooden moulds and dried. Good balls are distinguished by their superior weight, and by having a violet color within. These balls are further prepared for dyeing, by being beaten with wooden mallets on a stone floor until they are reduced to a coarse powder, which is then heaped up in the middle of the apartment and moistened with water. Fermentation arises, and after about twelve days it is pretty well dried by being turned over, and then it is made into a heap for the use of the dyer.

According to CHEVREUL, when the leaves of the plant are subjected to the action of the press, a residue of a ligneous nature, and a juice, holding in suspension sundry matters which give it a dull appearance, are obtained. Thrown on a filter, it leaves a greenish matter, or fecula, which is formed of chlorophyl, wax, indigo-blue, and a nitrogenous substance. The clear liquid, after passing through the filter, contains a nitrogenous body, part of which only is coagulable by heat; a red matter, resulting from the union of the blue color with an acid; a yellow principle; gummy matter; sugar; a fixed organic acid; free acetic acid, and acetate of ammonia; odorous and volatile principles, the latter having the odor of osmazom; citrate of lime; sulphates of lime and potassa; phosphate of lime, magnesia, iron, and manganese; nitrate of potassa; and chloride of potassium.

CHEVREUL has not discovered in these products any body possessed of the power of seizing upon oxygen in an energetic manner, and which would explain the action of the pastel in the indigo vat. Still, it cannot be doubted that the principles furnished by this matter intervene, to a certain extent, as combustibles, and that at least a part of their effect must be referred to this mode of action. The indigo should itself be selected with care. The Guatemala variety is preferred for the urinary, or Indian, and the Bengal product for the pastel vat.

WONGSHY.—In the *Journ. für Prakt Chem.*, for December, 1849, appeared an article by W. STEIN upon a new yellow coloring matter, which had come under his notice. An excellent translation of this appeared in the *Chemical Gazette*, from which the Editor makes the following extracts, hoping they may be found of use to the practical dyer.

STEIN says—Towards the end of last year, a new material for dyeing yellow, called *wongshy*, was exported on experiment from Batavia to Hamburg, a sample of which was obtained from M. VOLLSACK, merchant. Whether it has hitherto been applied as a dyeing material, and with what results, could not be ascertained. The following notice, therefore, will probably not be without interest.

The new dyeing material consists of the seed-vessels of a plant, which, according to information from M. REICHENBACH, belongs to the family of the Gentianeæ. The form of the unilocular capsules is longish-ovate, drawn out to a point next the end of the peduncle, and crowned upon the opposite and more obtuse one with the dried six-lobed calyx. They vary in size; but on an average their length is 1·5 to 2 inches, and the diameter at the thickest part 0·5; the color is not uniformly reddish-yellow, but at some places darker, at others lighter. The surface is more or less irregularly-waved with six to eight longitudinal ribs. The odor resembles saffron, and subsequently honey. The shell is pretty hard and brittle, but becomes quickly mucilaginous when chewed, imparting a yellow color to the saliva, with a slightly bitter taste; it swells up considerably in water. Inside the capsules there are a number of dark reddish-yellow seeds—in one specimen one hundred and eight were counted; they are not attached to the sides, but are imbedded in a hardened pulp, and so connected one with the other. These seeds are tolerably hard, soften but slowly when chewed, have no particular taste, but after some time produce at the point of the tongue a slight but peculiar sourish-sweet pungency, resembling the action of Paraguay rue. The pulp, on the other hand, cementing them together has a strong bitter taste, which is particularly perceptible at the back part of the palate.

The wongshy, especially when pounded, readily gives up to water, both at the usual temperature as well as on boiling, a coloring principle, which possesses such an enormous divisibility that two parts of the pounded capsules furnish one hundred and twenty-eight parts of a liquid, which, placed in a cylindrical vessel of white glass with a diameter of three inches, still appears of a bright wine-yellow color. The concentrated extract is very mucilaginous, and has a fiery red color, which on large dilution passes into a golden yellow, the red disappearing.

Alcohol, both absolute and of 0·863 specific gravity, when digested with the pounded fruit, acquires a fiery red color, which on dilution also changes to a golden color

When digested with ether at the ordinary temperature, it assumes a wine-yellow or brownish-yellow color, and leaves on evaporation a thick yellowish-brown oil, which possesses the odor of the fruit, a mild slightly bitter taste, deposits at 32° a small quantity of a solid fat, and does not become thick when shaken with subnitrate of mercury even after long standing, and consequently belongs to the drying oils.

The aqueous extract gelatinizes on the addition of alcohol, and the yellowish gelatin may be obtained perfectly colorless by washing with alcohol. The solution in water is not precipitated by acids; caustic soda produces a gelatinous precipitate only when in excess; added in small quantity, the liquid remains clear, but upon the addition of an acid deposits gelatinous flakes. Carbonate of potassa acts in a similar manner, with this difference, that an excess causes the liquid to become thick only after a much longer time, and that acids produce but a small flocculent precipitate. The solution is so completely precipitated by barytic water, that the liquid filtered from the precipitate, on evaporation upon platinum and ignition of the residue, does not show any trace of organic matter. Lime-water causes a similar separation, and acetate of lead produces a gelatinous precipitate.

A solution of gelatin produces in the aqueous extract a trace of a precipitate arising from tannin.

Protochloride of tin produces no change at the ordinary temperature, or after a long time; on boiling, a dark orange-colored precipitate results.

Acetate of lead produces no change.

Basic acetate of lead causes a turbidness at the ordinary temperature, and an orange-colored precipitate on boiling.

Protosulphate of iron changes the color into a dark brownish-yellow, without, however, a precipitate resulting either in the cold or on ebullition.

Alum, acetate of alumina, and acetate of zinc produce yellow precipitates only on boiling.

Barytic water causes a yellow precipitate at the ordinary temperature, which on boiling acquires a reddish tint.

Lime-water gave a pure yellow precipitate; solutions of gypsum and chloride of calcium are not precipitated by it even on boiling; well-water, with a considerable amount of carbonate of lime, does not precipitate the coloring principle even with the assistance of heat; it is consequently not able to decompose the combinations of lime with acids.

To ascertain the value of the wongshy coloring matter for the purposes of dyeing, one part of the pounded capsules was digested for twelve hours with twenty parts of lukewarm water, being frequently stirred, and the liquid then strained. The coloring matter is most quickly extracted in this manner, without its becoming gelatinous from the formation of paste, as would happen were the liquid boiled. Properly prepared samples of woollen cloth, some without any mordant, others mordanted with alum, protochloride of tin, acetate of alumina, and basic acetate of lead, were dyed with this extract at a temperature of about 104° Fahr.; the color does not turn out so pure at a higher temperature. The unmordanted cloth was dyed a beautiful and uniform orange color by one immersion; of the mordanted samples, those with alum and acetate of alumina were better than those with protochloride of tin; the least satisfactory was that in which basic acetate of lead had been used as mordant. The tone of the color was not altered by the three first mordants, but it was less intense, and the stuffs were not uniformly penetrated by the coloring matter. However, the samples with alum mordant gave perfectly satisfactory results after a second immersion. The coloring matter likewise combines readily and uniformly with silk, communicating to it a very glowing golden color, so that in this case also it is preferable not to have recourse to mordants. Cotton, as was to be expected, can only be dyed with the assistance of mordants, and the best results appeared to be obtained with tin mordants; the color was orange, of a very agreeable tint.

The color, both upon wool, silk, and cotton, resists soap perfectly; but alkalies give it a yellow, acids and tin salt, a red tint. By this behavior it differs from the color of annotta, with which, as will subsequently be seen, it possesses in other respects great resemblance—a resemblance which unfortunately exists as regards the action of light. When exposed to light, the color very soon fades upon cotton, less quickly upon wool; and in this case it is more permanent upon the unmordanted samples. It resists the light longest upon silk; and in this respect, when compared with the other known yellow colors, may be reckoned among the best.

STEIN obtained a beautiful yellow, with a faint tint of red, by mordanting the woollen cloth with lime-water, and immersion in the boiling vat; it resists the soap perfectly, and the action of light much better than the orange. It is altered in a similar manner to the orange, by alkalies, acids, and tin salt, only less. Several very beautiful shades of yellow may be obtained by adding pearlash or caustic potassa to the dye, and immersing the unmordanted fabric at the ordinary temperature. The union of the color with the fibre takes place very quickly and very uniformly. By the addition of one part pearlash to thirty parts dye liquor, a yellow was obtained with a remarkable glow from a slight admixture of red. By the addition of twice the quantity of pearlash, a lively yellow, with a faint tint of green, was obtained. A still larger amount of pearlash cannot be used, as it renders the color dull and impure. With caustic potassa, instead of pearlash, STEIN obtained in the first place a pure brilliant yellow, with less red than with the pearlash; in the latter case, a beautiful canary-yellow with a shade of green. Ammonia acts in the same manner, but the color, under all circumstances, contains more red. The color also appears of a somewhat different shade when the fabrics are first immersed in the dye liquor, and then, after being washed, placed in an alkaline bath.

In the case of silk and cotton, the effect of alkalies is similar, but less apparent, because the silk and cotton fibres imbibe less of the coloring substance than those of wool.

That this color resists the soap is self-evident; but it also suffers less from the action of light than the orange, and when fabrics so dyed are passed through an acetic or hydrochloric acid bath, a brilliant aurora color is obtained. This interesting behavior, which the wongshy coloring matter has in common with that of annotta, is explained by the chemical character of the former, which is a weak acid; it combines with the alkalies, and with the alkaline earths, as is evident by the precipitation with baryta and lime-water. Its combinations with the former possess a pure yellow color, and are decomposed by stronger acids, when the liberated coloring matter separates of a brilliant vermillion color. But the coloring matter thus separated is no longer the same as that which was originally contained in the aqueous solution, for it is now perfectly insoluble in water, and is only dissolved in small quantity, and of a golden-yellow color, by absolute alcohol, ether, and spirit of 0·863 specific gravity. In the moist state it has a vermillion color; when dry and in the purest state, it is brown-red, like ratanhia extract, and is easily reduced to powder; but if it still contains sugar and fat, it has a beautiful yellowish-red color in thick layers, whilst in thin layers it is yellow and transparent, and becomes moist in the air. On heating the pure substance upon platinum, at first yellow vapor is given off, and at some spots the color becomes pure yellow; it subsequently turns black, fuses, and chars. The residual cinder is difficult to burn; the yellow vapors condense, when the experiment is made in a glass tube, into yellow oily drops. Concentrated sulphuric acid renders it scarcely perceptibly blue, and the acid acquires the same color, which quickly passes into violet and brownish-red, whilst the coloring matter slowly dissolves. Water separates from this solution a dirty yellowish-grey flocculent substance.

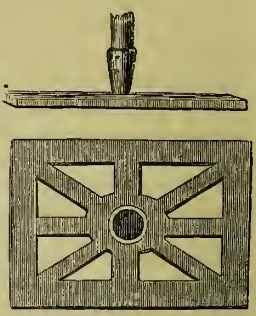
The reaction of the wongshy coloring matter which has just been mentioned, has no resemblance with the reaction of sulphuric acid upon annotta, for the liquid never acquires a pure blue color, as is the case with annotta, but is violet from the first, and only for a minute.

It dissolves readily in caustic ammonia and caustic soda with a golden-yellow color.

VATS, THEIR CONSTRUCTION AND WORKING.—A solid dye of indigo-blue is given to wool by plunging it into an alkaline solution of indigo-white, and then exposing it to contact with the air. The solution of indigo-white is prepared in a vessel usually from eight to nine feet in depth, and six to seven feet in diameter, which should be made of wood or copper, and always bears the name of *vat.* This size is very convenient for the requisite manipulations, and presents a large volume of water, which, when once heated, is capable of preserving a high temperature for a long time. These vats are covered with wooden lids, divided into two or three equal segments, covered over with thick blankets. Without this precaution, the bath would be more or less exposed to the atmosphere, and a portion of the indigo, absorbing oxygen, would be precipitated. There would also be a great waste of heat.

A most necessary operation, and one of frequent recurrence, consists in agitating the deposit of vegetal and coloring matter which is formed in the vat, and intimately mixing it in the bath. For this purpose a utensil, called a *rake,* which is sometimes formed of a strong square piece of wood, set on a long handle, is employed. In this country it is generally made of iron with a wooden handle, as shown in Fig. 350, which exhibits a side view and also the flat piece detached. The workman takes hold of the handle with both hands, and, dipping the flat surface into the subsidence at the bottom of the vessel, he quickly draws it up until it nearly reaches the surface, when, giving it a gentle shake, he discharges the matter again through the whole liquor of the bath. This manœuvre is repeated until the whole of the deposit seems to be removed from the bottom of the vessel. Before the tissue is dipped into the dye-bath, it should be soaked in a copper full of tepid water; it is then to be hung up and beaten with sticks. In this state it is plunged into the vat, and thus introduces less air into the bath, while the fibre is more uniformly penetrated by the indigo solution. The cloth is now kept in a depth of from two to three feet below the surface of the liquid, by means of an open bag, or piece of network, fixed in the interior of an iron ring, which is suspended by cords, and fixed to the outside of the vat by means of two small iron hooks; the bag is thus drawn backwards and forwards without permitting it to come in contact with the air. When this operation has been continued for a sufficient length of time, the cloth is wrung, and hung up to dry.

Fig. 350



Flock wool, when dyed, is also enclosed in a fine net, which prevents the least particle from escaping, and which is fixed in the bath in the same way as in the foregoing case.

The many inconveniences attending the use of a wooden vat—the pouring of the liquor into a copper, for the purpose of giving it the necessary degree of heat, being necessary—have led to the general employment of copper or iron vessels. In England the latter are chiefly used. These are fixed in brickwork, which extends half way up their surface, whilst a stove is so constructed at this elevation, that the flame shall play around their upper part. By this means the vat is heated, and kept at a proper temperature, without the liquor being removed.

The potassa vats are usually formed of conical-shaped coppers, surrounded by a suitable furnace. These may be constructed with less depth, inasmuch as there is less precipitation induced in the liquor. By using steam for heating the vats, the employment of copper vessels might be dispensed with, and so a return to those of wood adopted.

The vats employed for dyeing wool are known under the names of the pastel vat, the woad vat, the potassa vat, the tartar lie vat, and the German vat.

The methods of dyeing by woad or pastel are given by DUMAS as follows:—

Pastel Vat.—The first care of the dyer, in preparing the vat, should be, to furnish the bath with matters capable of combining with the oxygen, whether directly or indirectly, and of giving hydrogen to the indigo. These advantages are found in the pastel and woad. The dyer must, however, be careful to employ those substances only which are incapable of imparting to the bath a hue which might prove injurious to the indigo. Madder is used along with the woad; and as this substance furnishes a violet tint when brought into contact with an alkali—hence, by the addition of indigo, it yields a still deeper shade.

The pastel vat, when prepared on a large scale, ordinarily contains from eighteen to twenty-two pounds of indigo. Eleven pounds of madder might suffice for this proportion; but the large quantity of water which one has to charge with oxidizable matters, must be taken into consideration. Even twenty pounds to a vat of this size have been employed, invariably with the best results. Bran is apt to excite the lactic fermentation, and should, therefore, not be employed in too large a quantity; seven to nine pounds will be found amply sufficient.

The weld is rich in oxidizable principles; it burns, sours, and passes into the putrid fermentation with facility. Some dyers use it very freely; but in this bath, an equal quantity of it to that of the bran is commonly employed. Sometimes weld is not added at all.

In most dye-houses the pastel is pounded before introducing it into the vat. Some practical men, however, maintain that this operation is injurious, and interferes with its durability, and such an opinion deserves attention. The effect of the dye-stuff, when reduced to coarse powder, is more uniform; but this state of division must render its alterations more rapid. When the bath has undergone the necessary ebullition, the pastel should be placed in the vat, the liquor decanted, and, at the same time, seven or eight pounds of lime are added, so as to form an alkaline lie capable of holding the indigo in solution. The whole having been well stirred, it should be allowed to repose for four hours, so that the little pellets may have time to become thoroughly soaked, and thus be prepared for fermentation. Some thick coverings are to be spread over the vessel, so as to preserve the menstruum from contact with the atmosphere. After this lapse of time, it is to be again agitated. The bath at this moment presents no decided character; it has the peculiar odor of the vegetals which are held in suspension and solution, and it has a yellowish-brown hue.

Ordinarily, at the end of twenty-four hours, but sometimes after fifteen or sixteen, the fermentative process is well marked. The odor becomes ammoniacal, while, at the same time, the peculiar smell of the pastel is easily perceived. The bath, hitherto of a brown color, now assumes a decidedly yellowish-red tint. A blue froth, which results from the newly-liberated indigoferous matter of the plant, floats on the liquor as a thick scum, being composed of closely agglomerated small blue bubbles. A brilliant pellicle covers the bath; and beneath, blue, or almost black veins may be distinguished, owing to the indigo of the pastel having an ascendant tendency. If the menstruum be now agitated, the small quantity of indigo which is formed floats on the surface of the bath. On exposing a few drops of this mixture to the air, the golden-yellow hue quickly disappears, and is replaced by the blue tint of the indigo. This phenomenon is due to the absorption of the oxygen of the air by the indigo-white of the pastel. Wool might be dyed even at this juncture, without any further addition of indigo; but colors furnished at this period are devoid of brilliancy and vivacity of tone, while the bath becomes quickly exhausted.

The signs above described announce, in a most indubitable manner, that fermentation is established, and that the vat has now the power of supplying to the indigo the hydrogen which is required to render it soluble—that contained in the pastel having been already taken up—and this, consequently, is the proper moment for adding the pulverised indigo.

It was stated above, that the liquor of the vat should be previously charged with a certain quantity of lime; ammonia generated by the pastel is also found in it, but a portion of these alkalies becomes saturated by the carbonic acid gas along with the acid principles of the madder and of the weld, as also by the lactic acid produced by the bran during fermentation. The ordinary guide of the dyer is the odor, which, according to circumstances, becomes more or less ammoniacal. The vat is said to be either *soft* or *harsh;* if the former is the case, it is requisite to add a little more lime. The fresh vat is always soft; it exhales a feeble ammoniacal odor, accompanied with the peculiar smell of the pastel, and lime is therefore introduced along with the indigo—from five to six pounds are usually employed—and after having stirred the vat, it is to be carefully covered. The indigo, being incapable of solution except by its combination with hydrogen, gives no sign of being dissolved until it has remained a certain time in the bath. It may be remarked, that the hard indigoes, as those of Java, require more than six hours for their solution. The vat should be again examined three hours after adding the indigo. The odor is generally, by this time, weakened; a further quantity of lime is again added, sometimes less, but mostly about equal in amount to the first portion; it is then to be re-covered, and again set aside for three hours.

After this lapse of time, the bath will be found covered with an abundant froth, and a very evident pellicle of a cupreous hue; the veins which float upon its surface are larger and more distinct than they were previously; the liquor becomes of a deep yellowish-red tinge. On dipping the rake into the bath, and allowing the liquid to run off at the edge, its color, if viewed against the light, is a well-marked emerald-green, which gradually disappears, in proportion as the indigo absorbs oxygen, and leaves in its place a mere drop, rendered opaque by the blue of the indigo. The odor of the vat at this instant is strongly ammoniacal, but the peculiar scent of the pastel is at the same time discernible. When so obvious a character as this is found in the newly-formed vat, the stuff intended to be dyed may fearlessly be plunged in; but the tints given during the first working are never so brilliant as those subsequently obtained. This is owing to the yellow tinctorial matters of the pastel, which, aided by the heat, become fixed on the wool at the same time as the indigo, and thus communicate to it a greenish tint. This accident is common both with the pastel and the woad vats, though it is less marked in the latter.

When the stuff or cloth has been immersed for about an hour in the vat, it should be withdrawn; it would, in fact, be useless to leave it there for a longer time, inasmuch as no more of the coloring principle could be taken up. It is, therefore, to be removed from the bath and hung up to dry, when the indigo-white, by attracting oxygen, will become insoluble, and acquire the well-known blue color. If the stuff be now again plunged into the vat, the shade will immediately become deeper, owing to renewed absorption of indigo by the wool. By repeating these operations, very deep shades may be communicated. It must not, however, be imagined that the cloth seizes only on that portion of indigo contained in the liquor required to soak it. Far from such being the case, experience shows that, during its stay in the bath, it appropriates to itself, within certain limits, a gradually increasing quantity of indigo. Here, then, is an action of affinity, or, perhaps, a consequence of porosity on the part of the wool itself.

The army cloth is usually dyed by means of the pastel vat, which gives the most advantageous results. The vats are in this case about eight and a half feet in depth, and five feet in diameter, into which from three hundred and sixty-one to four hundred and five pounds of pastel or of woad are introduced, after previous maceration. The vat is to be filled with boiling water, and twenty-two pounds of madder, seventeen and a half pounds of weld, and thirteen pounds of bran are then added to the bath. The mixture is to be maintained in a state of ebullition for about half an hour; when a few pailfuls of cold water are introduced, taking care, however, not to lower the temperature beyond 130° Fahr.; during the whole of this time a workman, provided with a rake, keeps incessantly stirring the materials of the bath. The vat is then accurately closed by means of a wooden lid, and surrounded by blankets, so as to keep up the heat. It is now put aside for six hours; after this time it is again stirred, by means of a rake, for the space of half an hour; and this operation should be repeated every three hours, until the surface of the bath becomes marked with blue veins; from six to eight pounds of slaked lime are then added.

The color of the vat now borders on a blackish-blue. The indigo is immediately introduced in a quantity proportioned to the shade which we wish to obtain. The pastel in the foregoing mixture may last for several months; but the indigo must be renewed as it becomes exhausted, at the same time adding both bran and madder. In general the following proportions are employed—

11 to 13 pounds of good indigo for 100 pounds of fine wool.

9 to 11 pounds of good indigo for 100 pounds of common wool.

9 to 11 pounds of good indigo for 131 yards of cloth dyed in the piece.

Modified Pastel Vat.—This vat is about seven feet in depth, and six and a half feet in diameter. It is made of copper, and heated by steam. The lid is composed of three segments, each of which is formed of two planks, about an inch thick, and strongly secured together by bolts.

The beating is performed in the usual way, with sticks, before the first dipping, after having moistened the cloth in tepid water. This operation is not subsequently repeated.

This vat is prepared with thirteen pounds of indigo, seventeen and a half pounds of madder, four and a half pounds of bran, nine pounds of lime, and four and a half pounds of potassa. Having filled the vat, it is heated to about 200°, and, as soon as the water is tepid, four hundred and forty-one pounds of pastel are introduced. The liquor becomes of a yellowish-brown color; small bubbles appear upon its surface, ordinarily at the end of four hours if the vat be heated by steam, but not until after eight or twelve hours where heat is applied by the common fire; in the latter case, the mixture should be stirred every three hours. When the liquor displays the signs of fermentation, the above-mentioned ingredients are added, and the vat covered over; it is then to be set aside, stirring it every three hours, or oftener if the fermentative action be very rapid. Each time that it is stirred, from two to four pounds of lime are to be added; if fermentation proceed quickly, even more is used, but in the contrary case less. After about eighteen hours, three pieces of common cloth, measuring twenty to twenty-five ells in each length, are plunged into the vat; when they have received six or seven turns, they are to be taken out again. The object of this is to remove the excess of lime from the bath. The vat is then set aside for three hours, when it is to be stirred, thirteen pounds of indigo, with two pounds of madder added to it, and heat again applied to the mixture.

If the vat contains a superabundance of lime, it will be unnecessary to add more; otherwise a further quantity is thrown in. During the night it should be covered with a cloth, and a workman left to watch it. It is usually stirred once before the morning; but if it be deficient in lime, it will require this manipulation to be more frequently repeated, and also fresh lime added to it. On the following day, the stirring should be continued every three hours, and so on for the next thirty hours, taking care to heat the vat from time to time. On the morning of the fourth day, the dyeing may be commenced.

The temperature should be maintained at a pretty uniform point; if it be too hot, the blue takes a red reflection, by reason of the madder contained in the liquid. A vat thus prepared will last three months; it may even be worked for double that period, but after the third month it appears to lose some of its indigo.

The power of the vat is maintained by introducing every night two and a quarter pounds of madder. A little indigo is also added twice or three times a week. These additions are made in the evening. After the former, the vat is left at rest for forty-two hours; with the latter, only for twenty-four, at the same time observing the precautions already indicated. At the end of three months, or sooner, when it is desirable to stop the working of the vat, the indigo is exhausted by continuing to charge it every night, for the space of a month, with madder, and dipping into it white cloths, or more particularly woollen tissues, which become more or less loaded with the indigo. This plan must be prosecuted until these matters take up no further color. The dippings are to be performed twice a day at first, but towards the termination only once. Many dyers make use of this bath for preparing a new vat; but it is better to throw this away, and make it up afresh with common water.

Woad Vat.—These vats are extensively employed at Louviers, and in the manufactories of the North of France. The bath is prepared in the same manner as for the pastel vat. The finely-cut root is introduced into the copper along with two pounds of pulverized indigo, nine pounds of madder, and fifteen and a half pounds of slaked lime. The liquor is, after the necessary ebullition, poured upon the woad. This substance contains but a very small quantity of coloring principle; and some indigo must, therefore, be added when preparing the vat, so as to indicate the precise instant when the mixture arrives at the point of fermentation so requisite for imparting hydrogen to the tinctorial matter, and for rendering it soluble. A large quantity of lime must also be employed, since the woad contains no ammonia resulting from previous decomposition, such as is found to be the case with the pastel of the South. When the vat is in a suitable state of fermentation, a rusty color becomes manifest, in addition to the signs already described in speaking of the pastel vat; besides the ammoniacal odor, the bath always retains the peculiar smell of the woad. The pounded indigo is now added, and the operator proceeds in the manner already detailed, to reduce it to a state of solution fit for dyeing.

The vats prepared by means of pastel have greater durability than those made with the woad; but it is thought that the colors given by the latter are more brilliant than those obtained from the former dye.

Indian Vat.—These vats are more simple and of more ready construction than the pastel or woad vats. A quantity of madder and of bran, proportioned to the weight of indigo which it is wished to employ, is boiled in water. After two hours' ebullition, some tartar-lies are added, which are also to be boiled for an hour and a half or two hours, so as to charge the bath with whatever soluble matter they may contain; after this ebullition the bath should be allowed to cool, and the indigo which has been previously ground is then to be introduced. Supposing that twenty-one pounds of indigo are employed, the following would be the proportions used in preparing this vat:—forty-one pounds of tartar-lies, thirteen pounds of madder, and five pounds of bran. These vats are usually mounted in coppers of a conical shape; a small fire should be kept up around them, so as to maintain a moderate and uniform heat. The indigo will usually be found dissolved at the end of twenty-four hours, often even after twelve or fifteen hours. The liquor has a reddish color in the new vats, and a green tint in those which are in a working state. The frothy surface, as well as the brilliant-colored pellicle, become manifested in this as in all other preparations of a like kind.

This species of vat has to be renewed much more frequently than the woad and pastel vats, from the indigo being more difficult to dissolve after a certain lapse of time. A moderate heat should be maintained in all these vats.

Potassa Vat.—This species of vat is extensively employed at Elbeuf for the dyeing of wool in the flock. It presents, in all respects, a perfect analogy with the Indian vat; in fact, the action of the tartar-lie, in the latter preparation, depends entirely on the carbonate of potassa which it contains. The ingredients used in the preparation of the potassa vat are—bran, madder, and the carbonate of potassa of commerce.

The deep shades are obtained in this species of vat with greater celerity than in all others, a fact which undoubtedly depends on the greater power which potassa has of dissolving indigo than is possessed by lime. Experience proves that the potassa vat has the advantage in point of celerity of nearly a third; but this is balanced by the inconvenience resulting from the darker shade, which must be attributed to the large quantity of coloring matter of the madder dissolved by the alkaline lie, and which becomes fixed on the stuff with the indigo.

To render this vat in its most favorable state, the indigo should be made to undergo a commencement of hydrogenation, before turning it into the mixture; for this purpose, a bath analogous to that in the vat is prepared in a small copper, to which the pounded indigo is added. This bath is maintained for twenty-four hours at a moderate heat, taking care to stir it from time to time. The indigo assumes a yellowish color, becomes dissolved, and in this state is turned into the vat: many delays and losses are thus avoided in its preparation; and, indeed, it would be desirable if a similar plan were adopted with all these compounds.

German Vat.—This vat is of nearly similar dimensions to that used for the woad, being three times the size of the potassa vat. Its diameter is about six and a half feet, and its depth eight and a half feet. Having filled the copper with water, it is to be heated to 200° Fahr.; twenty pailfuls bran, twenty-two pounds of carbonate of soda, eleven pounds of indigo, and five and a half pounds of lime, thoroughly slaked, in powder are then added. The mixture is to be well stirred, and set aside for two hours; the workman should continually watch the progress of the fermentation, moderating it more or less by means of lime or carbonate of soda, so as to render the vat in a working state at the end of twelve, fifteen, or, at the most, eighteen hours. The odor is the only criterion by which the workman is enabled to judge of the good state of the vat; he must, therefore, possess considerable tact and experience.

In the process of dipping, eighty-four, one hundred and six, or even one hundred and thirty pounds of wool are introduced in a net bag, similar to that used in the woad vat, taking care that the bag is not allowed to rest against the sides of the copper. When the wool has sufficiently imbibed the color, the bag containing it is removed, and allowed to drain for a short time over the vessel. In this way two or three quantities are operated upon in succession ; the vat is then removed, and set aside for two hours; one must be careful, from time to time, to replace the indigo absorbed by the wool, as also to add fresh quantities of bran, lime, and crystallized carbonate of soda, so as constantly to maintain the fermentation at a suitable point.

The German vat differs, then, from the potassa vat by the fact, that the potassa is replaced by crystallized carbonate of soda and caustic lime, which latter substance also gives to the carbonate of soda a caustic character. It presents a remarkable saving as compared to the potassa vat; hence the frequency of its employment; but it requires great care, and is more difficult to manage. It also offers considerable economy of labor: one man is amply sufficient for each vat.

Management of the Vats.—A good condition of the vat is recognised by the following characters:—The tint of the bath is of a fine golden yellow, and its surface is covered with a bluish froth and a copper-colored pellicle. On dipping the rake into the bath, there escapes bubbles of air, which should burst very slowly; when they vanish quickly, it becomes an indication that more lime must be added. The paste which is found at the bottom of the vat, green at the moment of its being drawn up, should become brown in the air; if, however, it remain green, this is a further sign that more lime is required. Lastly, the vat should exhale the odor of indigo. The operator usually completes the assurance of the vat being in a good state by plunging into it, after two hours' respite, a skein of wool, which, on being withdrawn after the lapse of half an hour, should present a green color, but change directly to blue. The materials of the vat are then once more mixed, and two hours after it may be considered ready for dyeing.

These vats, like those already described, are provided with a large wooden ring, the interior of which is armed with a kind of network, for the purpose of preventing the objects which are intended to be dyed coming in contact with the materials at the bottom of the vat; the precaution is taken, moreover, of enclosing the wool or cloth in bags. These tissues, when plunged into the bath, should remain there for a longer or shorter time, according to the shade which it is wished to obtain: one dipping, however, will never suffice for this object; usually the stuff is allowed to remain for half an hour only; it is then to be taken from the bath, wrung, and exposed to the air. This operation is repeated until the desired shade is procured; three hours are ordinarily allowed to elapse between each dipping. The heat of the vat should never be allowed to fall below 130° Fahrenheit. After each operation the bath must be well stirred, and fresh lime added; generally speaking, a pound a day will suffice; the indigo is re-established about every second day. When once this vat is well mounted, and one is careful to examine its working, from two to four batches a day may be dyed with it.

When the stuffs have acquired the desired shade, they are first to be washed in common water, and then in a very weak solution of hydrochloric acid—about one part in a thousand; after this they are again rinsed in pure water.

The Indian vat is much more easily managed than the pastel vat; it presents less danger of failure from the fact that it is quickly exhausted, and also from the fermentative process, which is so difficult to govern in the pastel vat, here not having time to change in character. It is prepared by first introducing an equal quantity of madder and of bran, and a triple quantity of potassa; this is to be gradually heated until it reaches a temperature of 167° Fahrenheit, and the indigo is then added, thoroughly agitating the matters for half an hour. The vat is maintained at a temperature of 86° to 100° Fahrenheit, by keeping it closely covered, and at the same time the mixture is to be stirred occasionally at intervals of twelve hours. It should by this time present a beautiful green shade, the liquor being surmounted by a copper-colored pellicle and a purplish froth. The dyeing may now be commenced, following the same course as with the pastel vat; but the stirrings being here repeated much more frequently than with the other mixture, a larger quantity of wool can be dyed within a given time. When the vat ceases to give a brilliant blue, it must altogether be renewed; if it be merely weakened, a small quantity of freshly-prepared liquor, containing a few pounds of potassa, and a little less bran and madder, is added to it. In giving the dark and the clear sky-blues, one must be careful to employ a quantity of indigo proportioned to the color which it is desirable to obtain, or, better still, the previously exhausted vat may be used for the dark blue.

When exposed to the influence of the putrid fermentation, indigo is decomposed and loses its color. If rendered soluble, it obeys the impulse communicated to the nitrogenized matters with which it is brought into contact, although, if macerated in pure water at the ordinary temperature, it is itself decomposed with great difficulty.

The pastel and the woad are very prone to the putrid fermentation, by reason of the large quantity of nitrogenous matters which they contain, as do all the cruciferæ; they require, therefore, considerable care in their employment.

When a vat is mounted, if the fermentation be allowed to continue unchecked, after the appearance of the blue froth and the other signs already indicated, the liquor will acquire a yellow color similar to that of beer; the froth will become white; it will give out a stale smell, and lose its ammoniacal odor; after a few days it will turn whitish, and exhale a smell at first similar to that of putrified animal substances; then it will acquire the odor of rotten eggs, and set free sulphide of hydrogen. The lime in the pastel and the woad vats, and the tartar-lie and potassa in the other mixtures, are used for the purpose of preventing these accidents.

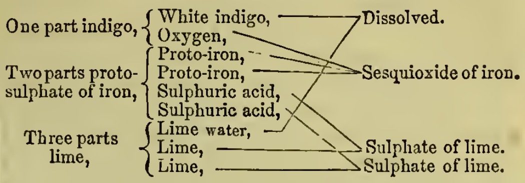
Besides the oxidized compound, which is formed by the combination of oxygen with the extractive matters of the plants held in digestion, there is a production of carbonic acid which saturates the alkaline lie, and forms a carbonate of lime in the pastel vat. This is found attached to the sides of the vat in such quantity, that the inside of these vessels becomes encrusted with it to a considerable depth. It is this product which dyers call the tartar of the vat; it effervesces with acids, and gives on analysis carbonic acid, lime, and a few particles of indigo. In the potassa vat, the solubility of the carbonated alkali prevents its deposition; but it is very probable that there is here a formation of some carbonated products, perhaps in part formed at the expense of the carbonic acid of the air.

The soluble extractive principle being the only matter which remains in solution in the bath with the indigo, the lime, *et cetera*, deposits are formed, which, varying both in their volume, and in the greater or less facility with which they are precipitated during the various periods of fermentation, lead to a more or less considerable waste of time. If a piece of woollen tissue be plunged into a vat which has been recently stirred, it will acquire a dark color, and will be found covered with brown stains, which are with difficulty removed. When the woad or pastel vat has been stirred, it need be left two or three hours only before plunging in the stuff, at least during the early months of its working, inasmuch as the pastel, being but slightly divided and attenuated, is readily precipitated; but when, by reason of its extreme division, in consequence of repeated operations, it is thrown down with less facility, the dipping should not be performed oftener than three times in the day.

The Indian vat requires less time than the others; it may even be dyed with, an hour after stirring the mixture. The potassa, being soluble, forms no precipitate; while the ligneous fibre of the madder and the pellicles of the bran become deposited with great facility. One can also dip with these vats much oftener than with those made by pastel or woad.

Cotton Vat.—The common blue vat for the dyeing of cotton differs from the preceding, both in preparation and materials; the only dyeing agent in it is indigo, and advantage is taken of a beautiful reaction of the ingredients to effect the purposes required. It has been stated—pages 592 and 593—that indigo is insoluble in water, and in most other menstrua, except strong sulphuric acid; but, when deoxidized, the blue indigo is converted into white indigo, in which state it is soluble in alkaline substances; but it becomes again blue indigo by absorbing oxygen, which it does from the air by a short exposure. Advantage is taken of these properties in making up the blue vat for cotton, and in the dyeing of that fabric. The indigo is first ground in water to an impalpable paste, of the consistence of cream. A quantity of this paste is put into a vessel of water, and there is added a quantity of protosulphate of iron and slaked lime, the latter in excess. The whole is well mixed by the rake, when the following reaction takes place:—

First, a part of the lime combines with the sulphuric acid of the sulphate of iron, liberating protoxide of iron, which having a strong attraction for oxygen, supplies itself from the indigo, reducing that body to the state of deoxidized indigo; in this condition, as already stated, it is soluble in alkaline waters, so that the lime, having been added in excess and in a state of solution, dissolves the white indigo, which forms the dyeing solution. The reactions may be stated thus:—



The proportions here given are equivalents. When cotton is dipped into this solution of white indigo, the fibres become filled with it. When lifted out and exposed to the air, the white indigo imbibes oxygen, and becomes converted into blue indigo within the fibre, and constitutes the dye—a beautiful example of chemistry applied to art.

The vats used for dyeing cotton cloth are similar to those described in the preceding pages for woollen and silk; only no heat is required for the cotton blue vat, and it is therefore sunk in the ground to a depth convenient for the operators to work at. This size of vat is also used by some for dyeing yarn, but more generally wine pipes or other large casks are employed for this purpose. These are sometimes sunk into the ground about half their depth, and in some cases they stand on the floor. Five of these constitute a set, and are worked together and kept of the same strength. The yarn being wrought in quantities of one hundred pounds, twenty pounds are passed through each vat. These vats are made up as follows:—Each is filled about three-fourths with cold water, and there is then added eight pounds indigo, sixteen pounds sulphate of iron—copperas—and twenty-four pounds newly-slaked lime. The whole is well stirred with the rake for half an hour, and this is repeated every one and a half hour for the first day. The time to stop this agitation is known by the solution becoming of a rich oak yellow, having large blue veins running through it, and a fine indigo froth on the surface. When these signs are all favorable, the vat is allowed to stand for several hours till all the solid matters settle, when it is ready for use. The reason for employing such deep vessels for vats is to allow room for the collection of the precipitate formed by the sulphate of lime and sesquioxide of iron, which, were they to touch the goods, would deteriorate the color. The mode of dyeing by this vat consists in simply immersing the goods, and working them in the liquor for fifteen minutes, taking out and wringing or pressing, and then exposing to the air. If the tinge is not sufficiently deep by one immersion or dip, this operation is repeated, but generally in a different vat, and so on until the required depth is obtained. The practice is to begin the dye in the weakest and oldest vats, and finish in the newest and strongest, which gives the finest bloom as a finish. All the liquor pressed or wrung out from the goods is put back into the respective vats, and when the operations are finished, the vat is raked and allowed to stand till next day. The yarn is well washed in cold water, and then dried. In some cases it is passed through a tub of water acidulated with vitriol till it tastes acid, and then washed, which adds a little brilliancy to the color when the shade is very deep, and tends to remove some of the iron which may have been fixed upon the fibre.

The quantity of liquid in one of these vats may amount to one hundred gallons, so that, by keeping the proportions stated, any quantity of dyeing solution may be made up. Sometimes, from defects in the materials, such as impurities in the indigo, lime, or copperas, or from other causes, the exact appearances stated may not come up satisfactorily, but a very little practice will enable the operator to vary the process, or add the proper ingredient, so as to produce a good vat. This is a matter, indeed, depending more on experience than on any instructions that can be given. If the indigo is of inferior quality, a greater quantity will have to be used. If the sulphate of iron is new and watery, not only more of that substance, but the addition of lime will be necessary; and if the lime is not newly slaked, it may not be found very effective, as lime that has stood for some time absorbs carbonic acid, and is thus deteriorated for the vat.

MINERAL DYES AND MORDANTS—ALUM.—The history of this article and the various processes for its manufacture have been already given.—See ALUM. Under this head it is stated that the earthy base, alumina, had a strong attraction for organic coloring matters, and hence was used for fixing such upon fabrics; but in order to have the alumina fixed within the fibres of the stuff to be dyed, it must previously be obtained in solution, and this can only be effected by converting the earthy base into a salt; hence the dye produced may be, and generally is, not the pure tinctorial matter adhering to the alumina, but in the state in which it is changed and fixed by the salt, the acid element of which acts an important part in altering the tint of the color. Thus pure alumina put into a decoction of logwood will become deeply colored, but the shade of the hue will be different from that obtained by putting into a similar decoction a solution of alum or acetate of alumina. Even the tints obtained by these last two mentioned substances will differ from each other. This is a circumstance which the dyer must ever bear in view, in regulating his tints either by mordants or alterants; and it is this chemical affinity of the color with the salt of the base that renders it so essential to good results, that the base, whatever it be, should be perfectly pure. Alum—as is stated in the article on that subject—containing the slightest trace of iron, is unsuitable for general use in a dye-house; and so important is this circumstance, that, at the risk of repetition, the method of detecting the presence of iron is appended:—

Dissolve a hundred grains of the alum in distilled water, and then add a few drops of ferricyanide of potassium—*red prussiate*; or first boil the solution, adding previously a few drops of nitric acid. After this, pour in by degrees a little pure carbonate of soda to neutralize the nitric acid, but not to precipitate any alumina; then add further a few drops of a solution of ferrocyanide of potassium—*yellow prussiate*; if any iron be present, a blue color will appear in both cases. Or, to another portion in solution, add a little gallic acid, and, if any iron be present, a slate-colored precipitate will appear. It is recommended that all these tests be applied so as to secure a pure article.

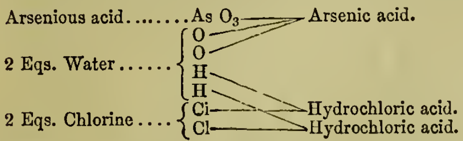
The only method of preparing alum for the dye-house is simply by dissolving it in water. About a pound of alum to the gallon of water makes a good solution. It is not much used as a mordant for cotton, in consequence, doubtless, of the strong attraction which sulphuric acid has for alumina; but it is extensively used in dyeing both silks and woollens, the fibres of which seem to act more powerfully in retaining and fixing the base.

Very nice shades of lavender and lilac may be dyed by making a strong decoction of logwood, and adding to it one pound of alum to the pound of logwood. After standing for a day, the cotton is wrought in this solution and wrung out. Light shades are dyed by adding some of this liquor to hot water, working the cotton in it for some time, and then finishing. This preparation is known as the *alum plumb tub*. It is principally used for light cotton cloth.

Alumina, dissolved in acetic acid, is extensively used as a mordant for cotton in various processes of dyeing, and is known in the trade as *red liquor*. The processes for its preparation, and the different results obtained, have been already described under *Acetate of Alumina*—see page 37—to which the special attention of the dyer is called. The modes of using it will be referred to under the particular processes in which its use is required.

ARSENIC.—This metal and its oxides have been already described.—See page 213. Except as a test, it is not very extensively employed in the dye-house, and fortunately so, on account of its highly poisonous properties. The principal use to which it was formerly applied, was for dyeing what are technically called *arsenic sages*, the coloring principle of which is Scheele's green, dyed by working the cotton through an arsenite of soda or potassa and sulphate of copper. With reference to this dye, and the evil consequences resulting from it, NAPIER makes the following remarks:—Common humanity, he says, dictates its complete abandonment as a dye. Nor is the evil so much in the operations of dyeing as in those that succeed: persons who have occasion to work with the yarns after they are dyed, suffer more severely than the dyers. The color being merely a precipitate of the arsenite of copper—a most deadly poison—upon the fibre of the yarn, to which much of it loosely adheres, it is readily disengaged as dust in the dry state, and in the process of winding, especially, much of it is unavoidably inhaled by the unfortunate operative. The result is, as might be expected, that health is seriously impaired, and not unfrequently the consequences are fatal. It is, in fact, consistent with our knowledge, that individuals of this class have never recovered from the effects of winding a quantity of arsenic sage-yarn, for which they were paid *one shilling!* Warpers also are subjected to the same baneful evil, although in a less degree; and even the weaver is not exempt from it. Altogether, indeed, the injury to the community by the use of this dye outweighs a hundredfold that arising from the unrestricted sale of poisons, against which so loud a protest has been raised. One feels fully convinced, moreover, that it is a gratuitous evil, and that dyers would very soon, under the pressure of a little public opinion, find means of avoiding it, and producing the color innocuously, and of a harmless character.—*Manual of Dye.*

Arsenious acid is occasionally used for testing the value of bleaching powder, by the process recommended by **GAY-LUSSAC**, which depends on the fact of chlorine converting arsenious acid into arsenic acid, the chlorine assuming hydrogen and becoming hydrochloric acid; thus:



A little sulphate of indigo put into the arsenious solution is not decolored, until all the arsenious acid is converted into the arsenic acid. It follows, therefore, that as the equivalent of arsenious acid is 99, while that of chlorine is 35·5, and it requires 2 proportions of chlorine to form arsenic acid, every 99 of the arsenious acid, converted into arsenic acid, will require 71 chlorine. The process may be conducted as follows, taking, for the sake of even numbers, one hundred grains of arsenious acid:—This is dissolved in about four fluid ounces of hydrochloric acid, which generally requires a little heat. The resulting solution is now diluted with six ounces by measure of distilled water, and the whole ought, therefore, to measure exactly ten ounces. It follows that each ounce contains ten grains of arsenious acid. To test bleaching powder, take one hundred grains of the powder, and rub it in a china or glass mortar with a little water; then add as much water as will twice fill an ordinary graduated alkalimeter; allow the coarser grains to settle; then fill the alkalimeter, and, as this is divided into one hundred parts, each part will contain half a grain of bleaching liquor. Take an ounce of the arsenious solution, and add to it a little sulphate of indigo, sufficient to render it a deep blue; then pour into this slowly the bleaching liquor from the alkalimeter, until the blue color disappears, stirring constantly during the operation; mark the number of graduations required to effect this change; and as every 10 grains of the arsenious acid was equal to 7·2 grains of chlorine, so the quantity of bleaching liquor taken to decolor the indigo will contain that amount of chlorine. Suppose, for example, it has required forty-eight graduations of the bleaching liquor to effect the change; this will be equal to 24 grains of bleaching powder, so that 24 grains of the powder will contain 7·2 of chlorine; and if 24 contain 7·2, 100 will contain 30. The powder has, therefore, 30 per cent. chlorine. These operations should be repeated three times upon each sample, and the mean of the three results taken. By a little experience, the whole process is found so simple that a few minutes will suffice to test a sample of bleaching powder. The arsenic solution is best newly made, and is found to lose its quality as a test by standing. This use of arsenic in the dye-house is not deleterious.

CHROMIUM.—This metal was first discovered by **VAUQUELIN** in 1797. It derives its name from its compounds being all of a brilliant color, but as a metal it resembles cast-iron in appearance. Hitherto, however, it has only been obtained in the state of a powder. It is very difficult to fuse, and is not subject to oxidation when exposed to the air. It resists the direct action of the common acids—sulphuric, hydrochloric, and nitric. It is found native in considerable quantities in combination with lead and iron. The latter combination, termed chrome iron ore, is its principal source, and is found in America, in different parts of the continent of Europe, and in Scotland. The general composition of the ore is one portion of oxide of iron, Fe O, and one of sesquioxide of chromium, $Cr_2\ O_3$.

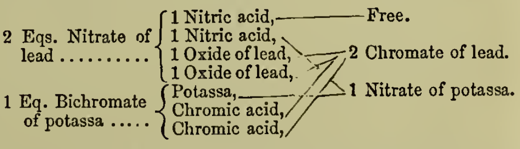
It is capable of combining with two proportions of oxygen, forming—

Sesquioxide,......................$Cr_2\ O_3$
Chromic acid,......................$Cr\ O_3$

The oxide is a beautiful green-coloured compound, and is generally obtained from the decomposition of the acid by processes about to be described.

The acid is a brilliant scarlet-red colored compound, and is prepared directly from the chrome ore by crushing the ore very fine, mixing it with a quantity of dried nitrate and carbonate of potassa, and then subjecting the whole to a strong heat in a reverberatory furnace. In this case, the nitrate of potassa is decomposed, supplying oxygen to the chrome oxide, which is thus converted into chromic acid; and this combines with the alkali, forming chromate of potassa, which is afterwards dissolved out by water. This chromate is then converted into the bichromate by the addition of acetic acid, which takes up half of the potassa. The bichromate is next crystallized from its solution, and constitutes the beautiful red-colored salt so extensively used in dyeing, and known in the trade as *chrome.*

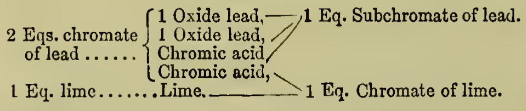
Particulars of the preparation of these salts and oxides, with the later improvements introduced, will appear under the article POTASSA and its Salts. Reference will here be made only to the uses and applications of the bichromate in dyeing. The introduction of this salt into the dye-house effected a complete revolution in certain departments of the art, and it still continues to make inroads upon old processes by new and more extensive applications. Its first use was the production of yellow with the salts of lead. By passing the goods through a solution of acetate or nitrate of lead, and then from that through a bath of bichromate of potassa, a beautiful yellow is obtained, the following reaction taking place between the salts, supposing nitrate of lead has been used:—



It will thus be seen, that when formerly the goods were passed through lead, and then into chrome, some free nitric acid was accumulated in the chrome solution. The same kind of reaction took place with acetate of lead, and this not only induced a strong tendency to change the shade of color, but was hurtful to the fibre, while, at the same time, the process was not economical. These circumstances produced a variety of improvements, which consisted in first converting the lead salt into a subsalt, where two proportions of lead were in combination with one of acid, which met one of the difficulties.

In the dyeing of green, where the cotton was first dyed by the blue vat, given at page 641, and then dyed yellow, as first described, the free acid had a very prejudicial effect upon the indigo; hence it was one of the most difficult dyes to produce of an equal tint. The subsalt of lead did away with this difficulty to a certain extent; but the solution of lead upon the fibre, mixing with the chrome, caused a great precipitation of chromate of lead, producing a rusty color and a loss of material; and, consequently, different solutions of lead were used, and also different matters put into the solution of chrome, which, after these remarks, the reader will be able to appreciate by the processes appended to this article for dyeing yellows, *et cetera.*

Shortly after the introduction of the chrome yellow dye, the dyeing of orange by the same salts came into practice, and was effected as follows:—A strong deep yellow was dyed upon the cotton; after which it was passed through lime-water brought nearly to the boiling point. This produced the following reactions, bearing in remembrance that the yellow dye upon the cotton is the chromate of lead:—



This subchromate of lead possesses a rich orange hue.

The different improvements effected in the dyeing of yellow have been adopted for orange. The object aimed at, with a view to the effective dyeing of this color, is to obtain a large quantity of chromate of lead fixed upon the goods, so as afterwards to produce a rich orange. The formation of subsalts of lead, by boiling the acetate of lead with litharge, has consequently been largely practised for the dyeing of this color.

Bichromate of potassa is also extensively used, along with catechu, for dyeing browns, fawns, drabs, and a great variety of other shades upon cotton. It has of late been much employed in dyeing woollens several shades of browns, blacks, drabs, and slates. With this fabric it acts the part of a mordant, probably by the chromic acid being reduced to the state of sesquioxide of chromium. Some dyers reduce the chromic acid into the state of chromic oxide, previous to using. The following method has been recommended for effecting this reduction:—Dissolve nine pounds of bichromate of potassa in five gallons of boiling water; then put ten pounds of arsenious acid into a boiler containing about twenty-five gallons of water; boil for a quarter of an hour, and allow the liquor to settle; decant the clear portion into a large vessel while the liquor is still hot, and then add to this clear solution the solution of bichromate of potassa, stirring all the time; allow the whole to stand till perfectly cold. It is now put through a filter, upon which is collected the oxide of chrome as a beautiful green-colored precipitate. This oxide is soluble in hydrochloric acid, and may be used, as the dyer finds it convenient, either as a mordant or otherwise. The method of dissolving this oxide in hydrochloric acid, is to dilute the acid with water until it no longer gives off fumes; it is then heated, and when hot, as much of the oxide of chromium is added as the acid will dissolve; the whole is then left to settle, and the clear portion is decanted. Any free acid which may still remain is neutralized by adding gradually a solution of carbonate of soda, until the oxide of chromium begins to be precipitated. The solution thus prepared has a dark-green color. This oxide is not extensively used for cotton, although some beautiful light drabs can be produced by a mixture of this oxide solution with carbonated alkalies; and a variety of shades, varying from blue-black to grey, may be obtained by working cotton in the above-neutralized solution of chromic oxide, and then adding a decoction of logwood. The strength of the solution and logwood must be regulated to suit the depth of color and the particular tint required. The appended recipes will serve to illustrate the use and value of chrome as a dyeing agent, premising that the quantities given are for dyeing ten pounds weight of cotton. Of course the operator may either enlarge or reduce the proportions, according to the quantity of goods to be dyed:—

Light Straw.—To a tub of cold water add four ounces of acetate of lead, previously dissolved; work the goods through this for fifteen minutes, and wring out; into another tub of water add two ounces bichromate of potassa; work the goods through this ten minutes, wring out, and pass again through the lead solution for ten minutes; wash, and dry.

Lemon Color.—Into a tub of cold water put one pound of acetate of lead, previously dissolved; work the goods in this for fifteen minutes, and wring out; into another tub of cold water put six ounces bichromate of potassa in solution; work the goods for fifteen minutes through this, and wring out; then put back, and work ten minutes in the plumbous solution; wring out, wash, and dry.

Deep Yellow.—To a tub of cold water add one pound acetate of lead, and one pound nitrate of lead in solution; work the goods in this for half an hour, and wring out; then in a tub of warm water add twelve ounces chrome, and work the goods from the lead through this for fifteen minutes; expose to the air for half an hour, then pass again through the lead and chrome, working the same time in each as before, and allow an hour's exposure out of the chrome the second time; then pass through the lead; wring out, wash, and dry. If not deep enough, a third dip may be given, observing the same rules.

Deep Amber Yellow.—Put into a tub of water one pound acetate of lead, and to this add gradually caustic potassa or soda, until the precipitate formed be redissolved, taking care not to add more alkali than is required for this solution. The goods are then wrought through this for half an hour; wring out, and then add eight ounces chrome in another tub of water, and work the goods in this for fifteen minutes; wring out, wash, and dry. Two or three ounces of sulphate of zinc may be added to the chrome solution with good effect. If a red deep amber be required, add to the chrome solution one half pint muriatic acid.

Chrome Green.—Dye a blue by the vat described at page 641; then, on the top of the blue, dye a yellow, by the last recipe. Of course the depth of blue and yellow will regulate the tint of green. So that the proportions named for the yellow may be smaller, and the dips or immersions repeated more or less frequently, as required. The principal difficulty is when a particular depth or shade of green is wanted, to ascertain the exact shade of blue to be given, as blue cannot be added upon the yellow. This is a matter, indeed, which can only be learned by practice; but a very short experience will suffice.

The Editor also annexes a few receipts for dyeing with bichromate of potassa upon woollens, the quantities stated being for five pounds of woollen, either in thread, cloth, or wool. It ought to be premised that the woollen must always be well cleaned before dyeing, and that the dyeing must always be performed at a boiling heat:—

Black.—Work for one hour in a bath with eight ounces bichromate of potassa, six ounces alum, four ounces fustic; lift, and expose to the air for a short time; wash well, and then work for one hour in another bath with four pounds logwood, four ounces barwood, four ounces fustic; lift, and add four ounces copperas in solution; work half an hour in this, and then wash and dry.

Blue-black is first dyed blue by the vat, or by ferrocyanide of potassium, or *yellow prussiate*, as will be afterwards described, and then proceeded with as directed in the above receipt, only using less materials.

Brown.—Work for half an hour in eight ounces of chrome; lift, and expose till cold; then into a new bath work an hour in two pounds fustic, four ounces madder, three ounces cudbear, four ounces tartar, two ounces logwood; lift out, and dry; or it may be washed before drying.

Rich Yellow Brown.—Work for an hour in the following bath: two ounces bichromate of potassa, two ounces argol, two ounces alum; wash from this bath; then work about forty minutes in another bath made up with two pounds fustic, one pound madder, eight ounces peachwood, four ounces logwood; wash out of this, and dry. This gives a very beautiful brown; and a great variety of tints and shades may be made by varying the quantities of the last bath, with the same preparation as the first bath.

Rich Yellow.—Work for half an hour in a bath with three ounces chrome, two ounces alum; lift, and expose till well cooled and drained; then work for another half hour, without previous washing, in another bath with five pounds fustic; wash out, and dry.

Bottle Green.—Work for an hour in a bath with two ounces chrome and four ounces alum; lift out, and expose to the air for some time till the goods are cold; then work for an hour in a second bath with three pounds fustic, one and a half pound logwood; wash out, and dry.

Invisible Green.—Work for an hour in a bath with three ounces chrome, four ounces alum; lift, and expose to the air for some time; then work for an hour in a second bath with two pounds fustic, three and a half pounds logwood; wash out, and dry.

By comparing these two last receipts, it will be seen that the different shades are produced by varying the proportions of the same stuffs, and they will serve as a guide to the amateur.

Olive.—Work for an hour in a bath with four ounces chrome, two ounces alum; lift, and expose for some time to the air; then work for an hour in a bath with three pounds fustic, one and a half pound camwood, one pound logwood; lift out, and dry.

Purple.—Work the goods half an hour in a bath with one ounce chrome, one ounce alum; lift out, and wash in cold water; and then work half an hour in a bath with two pounds logwood, one pound peachwood; lift, and add one ounce of alum in solution; work in this for twenty minutes; wash, and dry.

If a light and redder shade be required, use less logwood and more peachwood; and if a darker shade, more of each.

Rich Green Drab.—To the dye bath add one ounce bichromate of potash, half an ounce alum, half an ounce tartar, and work the goods in this half an hour; lift out, and wash through cold water. Make up a new bath of water, and add four ounces logwood, two ounces fustic, one ounce barwood, or half an ounce peachwood; work the goods again through this second bath half an hour; wash, and dry.

Shades of this can also be varied by using different proportions of stuffs.

Rich Drab.—Dissolve half an ounce of bichromate, and add the required quantity of water; work in this for half an hour; lift the goods, and add one ounce of logwood; work again for half an hour; lift out, wash, and dry.

Different shades of this drab may be made by varying the quantities of the dyestuffs.

These recipes might be greatly multiplied; but those which have been given will serve as a guide for practice, and will sufficiently illustrate the extensive use to which bichromate of potassa has been applied in the dyeing art. These directions are also so simple and easy, that the amateur may put them in practice without the risk of failure; and it may be mentioned, that the quantity of water to be used is not material; this will be regulated according to the size of the vessel, and the number of goods to be dyed; but there should always be enough of water to cover the goods without the necessity of pressing them down. Rules for making up decoctions and other manipulations will be given at the end of this article.

COPPER SALTS.—These have been already treated of under COPPER and ACETIC ACID, and do not require to be further noticed here, except with reference to their use as dyeing agents. In the dye-house they are not very extensively used; they have a peculiar influence in many operations, from their property of yielding oxygen, and thus, for many purposes, they act a very important part, well known to practical men, but not yet easily defined on scientific principles. They are very little used in the dyeing of cotton goods.

Sulphate of copper is used among catechu for destroying the gummy principle in that drug; it is also employed with copperas, for certain tints and shades of black and brown upon cottons and woollens.

Acetate, or subacetate of copper, is, however, the salt most in fashion for an alterant, its acid being not so destructive to vegetal dyes as that of either the sulphate or nitrate. The last-named salt, when used, is generally prepared by the dyer himself, by dissolving a piece of metallic copper in nitric acid, mixed with a little water, adding as much copper as the acid will take up.

Vast quantities of this salt are obtained from the etching of copper rollers, and in many large print-works it is looked upon as a sort of refuse, and sold at a small cost. An ingenious application of this waste salt, and which is well worthy the notice of dyers and others who may have quantities of this waste article, was lately patented by a Glasgow manufacturing chemist, Mr. DUNN. His process consists in adding to the acid salt as much litharge as will combine with any free acid present; and after effecting this saturation, he inserts into the solution sheet-lead, upon which is deposited the copper; the whole solution is by this means converted into nitrate of lead, which is evaporated and crystallized. The precipitated copper is separated from any lead that may remain, and then heated sufficiently to effect oxidation; after which it is digested in sulphuric acid and water, forming the sulphate of copper, which is boiled down and crystallized.

IRON SALTS.—Some of these have earlier received attention—see ACETATE OF IRON; others will be treated of in their proper places; at present the uses of these salts in the dye-house will be explained. An important application of sulphate of iron—copperas—has been already referred to when treating of the common blue vat; but the selection of copperas for this purpose is a highly important consideration. There is a watery-looking pea-green colored crystal very common in the Scotch market, and which is not a good copperas for the blue vat; when tested, it invariably exhibits a deficiency of iron, and a higher proportion of acid than theory allows; and when such copperas is used for a vat, a greater quantity of it is required, and also more lime; the precipitate in the vat takes a much longer time to subside, producing what is technically termed *swimming*, which affects the dye, and is an annoying circumstance to the dyer. The copperas best suited for the blue vat should have a dark rusty-green color, and care should be taken that it contains no impurities, such as copper, zinc, or alumina, as the presence of these matters neutralizes the effects of iron in reducing the indigo, naturally suggesting that the dyer should be acquainted with the means of testing the quality and value of his stuffs. The following are a few simple rules for copperas:—Dissolve one hundred grains of the crystals in four ounces of distilled water in a glass or china vessel, add to the solution one-fourth of an ounce of nitric acid, and bring the whole to ebullition; this converts the iron to the state of sesquioxide. Divide the solution into four equal parts. To one part add an excess of caustic potassa, and boil for ten minutes; pass the whole through a filter, and fill the filter several times with water to wash the precipitate, which may afterwards be thrown away; to the clear solution add sulphuric or hydrochloric acid until it reddens blue litmus paper; then add ammonia till the solution smells of that liquid, and allow it to stand over for half an hour. If a white precipitate appears, either immediately or after standing, then alumina is present, and the copperas should not be employed for the blue vat.

To another part of the original solution add ammonia in excess, and filter, washing the precipitate as before; but this precipitate is not to be thrown away. If copper be present, the solution will have a bluish tint, and the copperas should not be used for the vat; if no blue tint shows itself, and no alumina, dry the filter with the precipitate, and then burn the whole at a red heat for ten minutes, or until the filter is all consumed; sesquioxide of iron remains, and this must be carefully weighed; then, as eighty of this is equal to seventy-two protoxide, so will the weight of the residue obtained be equal to the protoxide originally in the copperas; and the quantity of the solution being a fourth of the one hundred grains, the result is multiplied by four for the per centage. The following is the theoretical composition of copperas:—

	Centesimally represented.
Protoxide of iron,	25·9
Sulphuric acid,	28·8
Water,	45·3
	100·0

So that, if the quantity of protoxide of iron be less than twenty-six per cent., the copperas is inferior; it ought to be nearer to twenty-seven for good old copperas.

To the third portion of the original solution add a solution of chloride of barium, so long as there is any precipitate formed, and allow it to stand for half an hour; then filter, and wash the filter till a little of the water passing through, caught in a clean glass, gives no precipitate with sulphuric acid; when thus washed, the filter with its contents is dried, and then burned in the same way as the iron precipitate; the remainder is weighed, and calculated by this equation:—As 116 sulphate of baryta is equal to 40 sulphuric acid, so is the weight obtained to the sulphuric acid present in the copperas; the result multiplied by 4 gives the per centage, which should not exceed 29 per cent., as given above. If, as is often the case, the result be 30 per cent., there is something wrong.

If these operations are carefully performed, the fourth portion of the liquor will not be required; and if the results of the trials be satisfactory, the dyer may go on to use his copperas without fear, either for the blue vat or any other purpose; and although little impurities may not be of so much consequence in some of the uses to which copperas is applied, as when it is employed for the vat, still the pure article is always the best and most economical.

Copperas is extensively used in the dye-house for a variety of purposes, from the property it possesses of forming black compounds with vegetal astringent substances, such as gallic acid and tannin; and, as already stated under the various vegetal dyes, many of these contain astringent matters. Iron is consequently of universal use, both as a mordant or base, and as an alterant, and, from its sombre effect when used as an alterant, it has got the significant epithet of *saddening*.

In this salt, as with alumina, although the oxide of iron has a powerful attraction for the vegetal matters, still the acid which is in union with the oxide exercises a strong resistance. Thus, copperas having an excess of acid will not give so deep a dye upon cotton with the same quantity of sumach as dry neutral copperas, nor will either give so deep a tint as the same quantity of oxide of iron if held in solution by acetic acid. Hence acetate of iron is a more powerful mordant than copperas. Moreover, the reaction of acetic acid upon the other coloring matters that are often present in the vegetals, renders that salt of iron much more useful than copperas for many purposes—see page 41. The latter, however, is most generally used in the dye-house. It is much cheaper, and can be applied with greater facility. Solutions of copperas are liable to become slightly changed by attracting oxygen, and the metal being converted into the sesqui. Iron does not in that state suit well for dyeing with astringent matters, as the peroxide reacts upon the vegetal, and causes loss.

Upon this reaction, and the effect of iron salts upon tannin and gallic acid generally, Professor Calvert has made some interesting investigations. The conclusions at which he arrives are these:—1. There can be no doubt that tannic acid is the matter in tanning substances which produces black with iron mordants. 2. That the reason why gallic acid produces no black dye is to be found in the circumstance, that it reduces the peroxide of iron in the mordant, forming a colorless and soluble gallate of protoxide of iron. 3. That gallic acid has the property of dissolving iron, and thus lays claim to the character of a true acid, whilst tannin, not having this action, appears to be in reality a neutral substance. These observations, some of which had been previously pointed out by Napier, must be of considerable importance to the dyer, and they agree with experience.

Copperas is also used as a mordant for dyeing blue by ferricyanide of potassium. Thus, ten pounds of cotton may be dyed a good rich blue, by working it for fifteen minutes in a solution of four pounds of copperas, wringing from this, and then working through a solution of four ounces of the ferricyanide; finally, washing in cold water containing an ounce of alum in solution.

Copperas is also used as a dye, by the oxidation of the iron within the fibre, thus:—

Iron Buff or Nankeen.—Take two pounds of sulphate of iron and dissolve them in warm water, and then add the requisite quantity of water for working the goods, work in this for twenty minutes, and wring out, and put them immediately into a separate vessel filled with lime-water, and work in this for fifteen minutes; wring out, and expose to the air for half an hour, when the goods will assume a buff color. If the color is not sufficiently deep, this operation may be repeated, working through the same copperas solution, but using fresh lime-water each time. The goods are then washed through clean warm water, and dried.

Chloride of Iron is another salt seen in the dye-house, and is prepared for use thus:—To four parts of hydrochloric acid add two parts water, and apply a gentle heat, then add iron in pieces or filings, so long as it continues to be dissolved; then pour off the clear liquid into a basin, and evaporate, when greenish-colored crystals of chloride will be obtained; but this salt crystallizes with difficulty, and deliquesces in the air, and should not be exposed. Instead of evaporating and crystallizing, the solution may be put into a bottle and reserved for use.

This salt is used for dyeing silks and woollens of a deep blue, and is preferred for that purpose to copperas.

To dye five pounds of silk a rich deep blue, add to water required to work the silk two pints of chloride of iron, and one pint *double muriate* or chloride of tin—see page 651; work in this half an hour; lift, and work in a solution of eight ounces ferrocyanide. If the color be now the required depth, wash out in water in which two ounces of alum have been dissolved; but if not sufficiently deep, put it again through the iron and ferricyanide solutions, and then wash out.

Five pounds of woollen will be dyed a deep blue by putting into the required quantity of water, one quart of chloride of iron, and one pint of chloride of tin; work in this for half an hour; lift, and work half an hour in a bath with four ounces of the ferricyanide. If the color is required deeper, repeat this through the same stuff, adding two ounces more red prussiate; then wash out in cold water, and dry.

Nitrate of Iron is another salt much used in the dye-house for several purposes. It is prepared by dissolving iron in nitric acid. Take four pounds nitric acid and one part water in a glass or stoneware vessel, and place it in a warm solution, then add clean iron so long as the acid continues to dissolve it with effervescence; take out any remaining iron, and, after settling for an hour, the clear solution is ready for use. One need hardly mention that the fumes given off in this operation are deleterious to health, and injurious to every metal or vegetal with which they come in contact. The chemistry of this salt will be given under the article Iron; but in the meantime it may be remarked, for the guidance of the dyer, that the salt thus prepared should be kept in the dark, as the light, according to Napier, has a wonderful effect upon its dyeing quality. If two equal quantities of the iron solution are kept, the one in the dark, and the other exposed to the sun's rays, for several hours, and then both are used for dyeing the same weight of goods prussian blue, that which has been kept in the dark will give a blue much deeper than that which was exposed to light. This salt is not used for the same purposes as copperas with astringent vegetal matters. Its principal use is for dyeing prussian blue, which may be performed as follows, the proportions being for ten pounds of cotton:—

For Sky Blue.—The cotton should be previously bleached, then to a tub of cold water, sufficient to work the goods in easily, add half a pint nitrate of iron, and then work in this for twenty minutes; wring out, and pass through one tub of clean water. Into another tub of cold water add four ounces ferrocyanide of potassium in solution, and about a wine-glassful of sulphuric acid; work the goods in this for fifteen minutes; wring out, and wash through cold water, in which is dissolved one ounce of alum; wring out, and dry.

To dye lighter or darker shades of sky-blue, use less or more of the iron and ferrocyanide; or should the shade be too light after passing through the processes described, by repeating the operations through the same tubs, only adding an ounce more ferrocyanide, the shade will be deepened nearly double.

Napoleon Blue.—The cotton to be bleached before dyeing. Into a tub of cold water add one imperial pint of nitrate of iron, and two gills hydrochloric acid, then add three ounces crystals of tin, or a pint of double muriate; stir well, and immediately enter the goods, and work for thirty minutes; wring out, and put directly into the *prussiate tub*, made up with water, into which is put a solution of twelve ounces ferrocyanide, and one wine-glassful of hydrochloric acid; work in this for fifteen minutes, then wash out in clean water in which is dissolved two ounces alum. If a deeper shade of blue is required than these quantities will give, the goods are washed from the prussiate tub, without alum, in water, and passed again through the iron and ferrocyanide, and then washed out, as above, with alum in last water.

Royal Blue.—This is dyed in the same manner as the above; but the liquors are stronger—using two pints iron, two gills hydrochloric acid, and four ounces tin crystals. The prussiate tub is made up by dissolving in it one pound ferrocyanide of potassium, and adding one wine-glassful of sulphuric acid, and one glassful hydrochloric acid. All the other operations are the same as the preceding. If not sufficiently dark with putting once through, repeat.

For five pounds of silk the following proportions of stuffs are used:—

Sky Blue.—To a sufficient quantity of cold water to work the goods, add half a pint of nitrate of iron; work in this for twenty minutes, then wash out in cold water.

Into another vessel of cold water add three ounces ferrocyanide of potassium in solution, and one ounce, by measure, of strong sulphuric acid; work through this for ten minutes, then wash in cold water, in which an ounce of alum has been dissolved, and finish.

Royal Blue.—Into a vessel with cold water add two pints of nitrate of iron; then take one pint water and half pint hydrochloric acid, and to this add three ounces crystals of tin; when dissolved, add this to the vessel containing the iron, or one pint double muriate of tin; stir well, and enter the goods immediately, and work for half an hour.

Into another tub dissolve eight ounces of the ferrocyanide, and add to it two ounces, by measure, of sulphuric acid; the goods are wrung out of the iron solution, and put directly into the second vessel with the ferrocyanide, working for fifteen minutes; then wash out in cold water, having two ounces of alum dissolved in it, and finish.

Should the shade not be sufficiently deep, instead of washing in the alum water, they may be put back into the iron solution, and again through the ferrocyanide in the same way, and work the same time as first, only adding two ounces of the latter salt before entering the second time into that vessel; then finish as stated.

Deeper shades are obtained by using more iron and tin, or by giving several dips.

Some wash out the iron solution before going into the ferrocyanide in one water, and also wash it out before putting back into the iron; the shade by this will not be so deep with the same stuff, but there is less risk of an unequal color.

Woollens may also be dyed different shades of blue with nitrate of iron, observing the general rule, that the woollen must be wrought at a boiling heat. For five pounds of this material the following processes are used:

Royal Blue.—Work for twenty minutes in a bath with one pound of the ferrocyanide of potassium, and lift; then take half a pint nitrate of iron, and add to it one ounce of the crystals of tin, or one pint chloride of tin; stir well for a few minutes, and then add this mixture to the bath, and work the goods in this for half an hour; wash out, and dry.

It is almost unnecessary to repeat, that different quantities will give various depths of color.

Nankeen or buff colors are dyed directly upon cotton by the nitrate of iron. To a tub of hot water add one pint of nitrate of iron, and work in this for half an hour ten pounds of cotton previously bleached; wash out in water, and dry. No process could be more simple and easy, and this produces a permanent dye.

These few receipts will show the importance of iron as a dyeing agent. Its further use in the dyeing of blacks, slates, *et cetera*, will be given at the close of this article.

Acetate of Lead.—See page 43.

Nitrate of Lead.—This salt, with the several oxides and other salts having the same base, will be treated of under the article LEAD.

Basic salts of the acetate of lead are prepared for dyeing oranges, and several deep shades of yellow, by boiling a solution of acetate, either white or brown, and adding to it a quantity of litharge, which is taken up, forming salts having two, three, and sometimes six proportions of oxide of lead to one of acid. These are found to be more suitable than the simple acetate. The only use of these lead salts in the dye-house is for dyeing yellows, greens, and oranges. They have therefore no application apart from bichromate of potassa, which has been already given.

MANGANESE.—A few years ago, the salts of this metal were introduced as a dyeing agent in the production of browns, depending entirely upon the formation of an oxide of the metal within the fibre of the stuff.

The salts of manganese belong to the protoxide; but when the acid which is in union with the oxide is removed, the protoxide passes into the peroxide, which has a deep brown color approaching to black. So that when cotton was steeped or worked for a time in a solution, say of protosulphate of manganese, and then through a weak solution of an alkali, the acid and alkali combined and were dissolved, while the oxide was left on the cotton. Hence, by exposure to air, it absorbed more oxygen, and passed to a brown; or by passing the cotton through a little bleaching liquor, the oxidation of the manganese was immediately effected, and thus browns and fawns of various shades and depths were dyed, according to the strength of the manganese salt, or the number of times the operation was repeated. The colors produced by this means had a heavy dull appearance, and are now very seldom dyed, having been superseded by catechu, which produces similar colors of a lively rich hue.

PRUSSIAN BLUE.—For the manufacture of red and yellow prussiate—see article POTASSA *and its Salts.* Here the use of these salts in the dye-house for the production of prussian blue will be dwelt upon. Under the head IRON, in this article, it has been stated that the different salts of that metal have a kind of reciprocal action upon these two salts of potassa, and that, with the sesquioxide salts and yellow prussiate, there is produced the same deep blue color as with the protosalts of iron and red prussiate. This kind of action occurs with several metals, and gives the dyer a considerable power of varying his processes and tints. The following table exhibits these reactions:—

	Red prussiate.	Yellow prussiate.
Protosalts of manganese,	Brown,	White, becoming red.
Lead,	No precipitate,	White.
Sesquisalts of iron,	No precipitate,	Deep blue.
Protosalts of iron,	Deep blue,	Bluish-white.
Copper,	Yellow-green,	Brown.
Protosalts of tin,	White,	White.
Persalts of tin,	No precipitate,	Yellow.
Zinc,	Orange-yellow,	White.
Bismuth,	Yellow,	White.
Cadmium,	Yellow,	White.
Cobalt,	Red-brown,	Green.
Nickel,	Yellow-green,	Greenish-white.

These two salts—yellow and red prussiate—are of the utmost value to the dyer. From the above table it will be seen that different colors may be produced by using different metallic salts; as, for example, copper and ferrocyanide of potassium. By working the goods in a solution of sulphate of copper, and then passing them through a solution of yellow prussiate, a rich brown is produced of great permanency, and this method is occasionally practised.

The principal use of these prussiate salts, however, is in dyeing blues by the salts of iron, examples of which have been given under the head IRON, in this article; other instances will be appended towards the conclusion, but, in order to explain the nature of the process by which the color is produced, the yellow prussiate may be defined as a double salt of iron and potassium, combined with cyanogen, namely, one part cyanide of iron and two parts cyanide of potassium. Thus—

$$2\ (K\ Cy)\ Fe\ Cy \text{ or } K_2\ Cfy.$$

The mere introduction of oxide of iron into a solution of yellow prussiate, will not convert the iron into prussian blue; and therefore, if a piece of calico, having its fibres saturated with oxide of iron, were passed through a solution of pure ferrocyanide of potassium—yellow prussiate—there would be no blue dye obtained, as the potassium would retain the cyanogen, and prevent it combining with the iron. The presence of an acid is requisite to unite with the alkali-metal, thus setting the cyanogen free to combine with the iron. When the goods are dyed by lifting them out of the iron solution, and putting them directly into the solution of yellow prussiate, in that case the acid of the iron seizes the potassium, and a mutual transference ensues. Two equivalents of nitrate or sesquichloride of iron and three equivalents of ferrocyanide of potassium, yield one equivalent of prussian blue and six equivalents of chloride of potassium, as represented by the equation—

$$2\ (Fe_2\ Cl_3) + 3\ (K_2\ Cfy) = Fe_4\ Cfy_3 + 6\ K\ Cl.$$

So far as regards the method of dyeing just described, there is no difficulty; but when the cloth is impregnated with the iron salt, and the acid is removed either by washing or passing through an alkali, as is often done, in that case acid must be added to the prussiate solution to liberate the cyanogen. If care is not taken in practising this process, a certain loss will occur. When the acid is added to the prussiate solution, a great quantity of the cyanogen passes off as hydrocyanic acid, and there is formed a new compound of iron and the liberated cyanogen. This, indeed, is also a species of prussian blue, but the product is far short of what would be obtained if no acid had been added. These observations will guide the intelligent dyer in his mode of proceeding with this agent. The same remarks apply also to red prussiate in its practical application. Colors dyed by the prussiate should be exsiccated in a dry atmosphere; for heat and moisture have a strong action on prussian blue, producing first a reddish tint, which passes into lavender and then into grey, and if the action is continued the tint is completely destroyed. It is easily affected also by the sun's rays, and likewise by washing in distilled or rain water. All alkaline matters destroy it. In the deeper shades of prussian blue, where tin salts are used along with the iron, the color is much more permanent. All kinds of fabrics—cotton, silk, and woollen—admit of being dyed prussian blue.

TARTAR.—*Argol—Cream of Tartar—Bitartrate of Potassa.*—This salt is much used as a mordant for the dyeing of woollen stuffs. It is seldom employed alone, but mostly with alum, sulphate of iron, and chloride of tin. Its use, along with these bodies, is very important, owing, as is generally supposed, to a decomposition taking place, in which the sulphuric acid of the alum and iron, and the chlorine of the tin, unite with the potassa of the tartar, resulting in the formation of a tartrate of alumina, iron, or tin, which combines more easily with the woollen stuff. Upon this action DUMAS has the following:—

Cream of tartar, or bitartrate of potassa, constitutes by itself a feeble mordant, but which is very often used in dyeing light woollen stuffs, to which one may wish to give a delicate but brilliant shade. It is also employed in the dyeing of ordinary woollen goods, but here it is associated with alum, sulphate of iron, chloride of tin, *et cetera.* Its influence, under these circumstances, consists evidently in determining a double decomposition, from which a sulphate of potassa or chloride of potassium is produced, whilst the tartaric acid combines with the alumina, the sesquioxide of iron, or the oxide of tin. Now, it is very probable that the coloring matters remove the alumina, the sesquioxide of iron, or the oxide of tin, more readily from tartaric than from sulphuric acid. Moreover, the presence of free sulphuric acid would certainly prove injurious, as well to the stuff as to the coloring matter, whilst free tartaric acid can exercise no unfavourable action over them.

The operation of subjecting wool to the alum mordant is always effected at the boiling point; the mixture used in this process is a compound of alum and of cream of tartar. One of the objects of this addition is to free the bath of the carbonate of lime which the water generally retains in solution, and which, acting on the alum, would determine its partial decomposition by producing an insoluble subsulphate of alumina and potassa, and this accumulating on the stuff, and becoming unequally fixed upon its surface, would lead to stains or blotches on passing the material through the dye-bath. But, independently of the above effect, which might be produced by any acid, cream of tartar appears to be capable of effecting a further object, by inducing a double decomposition, which transforms the alum into a tartrate of alumina. However this may be, after one or two hours' boiling in the alum-bath, the cloth, which should be constantly agitated so as to cause a more equal application of the mordant, is withdrawn from the copper, and after thoroughly draining, it should be put aside for two or three days, when it is wished to dye it with any full-bodied color. Experience has proved that this repose after the use of the mordant greatly favors the union of the latter with the stuff. In applying the tin mordants, use is also made of cream of tartar. It is, moreover, an indispensable addition where it is desired to fix the salts of iron previously to dyeing in black.

Woollen cloth, on being dipped into a cold aqueous solution of alum, appropriates to itself a part of this salt, but without undergoing any very sensible alteration. MM. THENARD and ROARD have, indeed, proved that cloth, when thus treated by a cold solution of alum, gives up this salt to boiling water, and that, after a few washings performed at the boiling point, it will have parted with the whole of the alum which it had received in the cold bath. When, however, cloth is boiled in a solution of alum, it yields to this liquid a portion of its organic matter, which becomes dissolved; but, at the same time, it absorbs an equal amount of the alum.

It will now merely be necessary to show the action which wool undergoes when brought into contact with alum and cream of tartar at one and the same time. It is very possible that there may be in this case a simultaneous fixation of alum, as well as of the double tartrate of alumina and potassa, and of tartaric acid. The presence of alum in the cloth when taken from the boiling solution is very evident; that of the tartrate of alumina and potassa and of free tartaric acid is only presumable.

Tartar is often adulterated when sold to the dyer. Its adulterations are generally sand, carbonate of lime, alum, and sulphate of potassa. By boiling one hundred grains of the tartar in a solution of carbonate of potassa or borax, the sand, if any be present, will remain as an insoluble residue, and may be weighed.

Take another one hundred grains of the same, finely ground, to which add a little water, and then a little dilute hydrochloric acid; if lime be present, there will be effervescence. After allowing it to stand for half an hour, add ammonia till the solution smells of that alkali; then put the whole upon a filter, and wash; to the clear filtrate add a solution of oxalate of ammonia, which will precipitate the lime; this, when filtered and burned, gives the quantity of carbonate of lime in the sample.

Dissolve another portion in water, with a little hydrochloric acid, and filter; to a part of the filtrate add a few drops of chloride of barium; if a white precipitate is formed, sulphuric acid is present. To the other portion of the filtrate add ammonia; if no precipitate is formed by this, then the adulterant will be sulphate or bisulphate of potassa; but should there be a white gelatinous precipitate by ammonia, alum is present in the tartar. The latter salt is not injurious to the process to which the tartar is applied by the dyer; but it is well that he should know the quality of the stuff before using it. Oxalate of potassa and soda is occasionally used as a substitute for tartar, but is not so effective as a mordant.

TIN.—The oxides of this metal have been long known as a mordant for dyeing, as stated in the course of the historical remarks; and the salts of tin are still among the most useful and extensively used of any substances in the art. The oxides have a strong affinity for vegetal coloring matters, and also a strong tendency to combine with or become insoluble within the fibres of the goods submitted to their action, thus rendering them peculiarly suitable as mordants. Tin combines with oxygen in different proportions, while its oxides combine with acids, and give rise to a series of salts of distinctive qualities, but all more or less useful in dyeing. These oxides have the following composition:—

Protoxide,	$Sn\,O$
Sesquioxide,	$Sn_2\,O_3$
Peroxide,	$Sn\,O_2$

The first and last of these form with acids permanent salts, known by the affixes *pro* and *per*, or distinguished as stannous and stannic salts. The sesquioxide salts are generally found and used in combination with other salts, such as those of iron, forming also important compounds for dyeing purposes.

Protochloride of Tin—commonly called salts of tin—is obtained in the market in the form of white prismatic crystals, which, according to Dr. PENNY, contain two equivalents of water, and are therefore composed of—

		Centesimally.
1 Eq. Tin,	59·0	52
1 Eq. Chlorine,	35·5	32
2 Eqs. Water,	18·0	16
	112·5	100

Other chemists, however, have assigned three atoms of water, in which case the composition will be—

		Centesimally.
1 Eq. Tin,	59·0	48·1
1 Eq. Chlorine,	35·5	29·5
3 Eqs. Water,	27·0	22·4
	120·5	100·0

The quantity of tin found in the salts of commerce generally agrees better with the latter analysis than the former. When these salts are put into water they produce a milky-colored solution, owing to the formation of an oxychloride of tin, which is insoluble. A little hydrochloric acid put into the water prevents this to a large extent.

Besides these crystals of tin, there are also obtained in the market solutions of protochloride of tin, under the name of *single* and *double muriate*. The former is a solution of tin in hydrochloric acid, with excess of acid, and the whole diluted with water. The quantity of tin in good single muriate is 12 per cent.

Double muriate is the same salt as the single, but more concentrated, having in it about 25 per cent. of tin. Both these salts vary very much in quality, and should always be subjected to a testing process. That recommended by Dr. PENNY is very easy and simple, and also very correct in its results; here the Editor appends it at length:—

The principal object of the present communication, says the author, is to make known a ready process for estimating the value of protochloride of tin.

This compound, it is well known, is extensively employed by dyers and printers, under the names of crystals, or salt of tin, and single and double muriate of tin, the first is the salt in its crystallized state, and the others are solutions of it in water, with excess of hydrochloric acid. The consumption of these articles is very considerable. In Glasgow alone, the production of crystals of tin, in the course of a year, is estimated at from one hundred and fifty to two hundred tons; and in Manchester and its neighborhood, the annual consumption is even greater than this, being perhaps not less than from two hundred and fifty to three hundred tons.

In common with other chemical products used in the arts, these preparations of tin are of course liable to become contaminated with accidental impurities; and there is no doubt that, by some makers, they are occasionally adulterated, for the purpose of economising the tin, though the practice, PENNY is led to believe, is rarely carried to such an extent as formerly prevailed. Metallic zinc was at one time freely added in the process of dissolving the tin in hydrochloric acid, not only as a substitute for the more expensive metal, but because it assisted, as many considered, in giving to the crystals the peculiar pearly or silky lustre for which they are usually esteemed. Besides zinc, he discovered also the presence of minute quantities of arsenic, sulphates, chlorides of sodium and magnesium.

At the present time, however, he feels satisfied that the leading makers of these articles in Glasgow do not intentionally add any metallic sophistication. The principal adventitious matters contained in the crystallized chloride, are water and excess of hydrochloric acid, arising from imperfect drainage of the crystals. This is particularly the case with fibrous or feathery crystals, which have the power of retaining mechanically a considerable proportion of the mother-liquor.

The value of these preparations, as respects the several purposes to which they are applied in the tinctorial arts, depends evidently on the amount of tin they contain; it being also essential that the metal should exist exclusively in the state of protochloride.

A simple process for estimating the quantity of tin in commercial samples of these articles, has long been a desideratum among practical men. The common method for the determination of tin by the agency of nitric acid, is quite inapplicable to the analysis of the protochloride; as, during the necessary ebullition, a considerable proportion of bichloride is formed, which, from its ready volatility, would be expelled in the course of the subsequent evaporation, thereby involving a serious loss. Another method, which was submitted to repeated trials, and which was capable of giving very exact results, consists in precipitating the tin by metallic zinc, and afterwards converting it into the binoxide; but these operations are much too tedious, and involve too many nice manipulations, to be available for general purposes. The process by sulphide of hydrogen is for the same reasons even more objectionable.

The agent which PENNY proposes to employ is bichromate of potassa. Its application is based upon the fact that chromic acid, in presence of free hydrochloric acid, converts protochloride of tin into bichloride; the chromic acid becoming sesquichloride of chromium. The reaction that takes place with bichromate of potassa is represented in the following equation:—

$$3\ \mathrm{Sn\,Cl} + \mathrm{KO},\ 2\ \mathrm{Cr\,O_3} + 7\ \mathrm{H\,Cl} = 3\ \mathrm{Sn\,Cl_2} + \mathrm{K\,Cl} + \mathrm{Cr_2\,Cl_3}, + 7\ \mathrm{HO}.$$

The operations which the present process involve are easily performed, and are precisely similar to other well-known centigrade methods of analysis. A normal solution of the bichromate is added to a known quantity of the chloride of tin dissolved in water, till, on being tested with a solution of acetate of lead, a slight excess of the chrome salt is indicated by the production of yellow chromate of lead. The amount of metallic tin is then deduced from the quantity of bichromate of potassa consumed. Centigrade methods of valuation are now so extensively used, that, to scientific chemists, the necessary manipulations will at once be obvious; but as the idea is to render the process available to practical men, a detailed statement of the mode of proceeding, it is now deemed necessary to subjoin. In the first place, therefore, the operations for estimating the value of commercial specimens of crystals of tin will be described; and afterwards the process for testing the prepared liquors, called single muriate and double muriate of tin, explained. Then the results of some of Dr. PENNY'S experiments will be given, showing how he ascertained the true composition of the crystallized protochloride.

Crystals of Tin.—This salt is usually sold to the printer in jars, containing from two to three hundredweight each. A fair sample, which should not be less than one or two pounds, is taken from the bulk, and triturated in a mortar until thoroughly mixed. Very frequently this operation requires considerable attention, as the crystals, in consequence of their dampness, are apt to cake under the pestle.

One hundred grains are then weighed out, put into a basin with two ounces of water and half an ounce of hydrochloric acid, and the mixture gently heated. 83·2 grains of bichromate of potassa are next dissolved in about two ounces of tepid water, and the solution carefully transferred to an alkalimeter of one hundred measures, which is filled to the top line of the graduations by the addition of water, and then inverted on the palm of the hand for the purpose of rendering the liquid uniform throughout. This quantity of bichromate of potassa, as will be presently shown, is exactly equivalent to one hundred grains of pure metallic tin; and hence, each measure of the alkalimeter will be equivalent to one grain of the metal.

The alkalimeters in common use for centigrade analysis, are generally made of such a capacity, that one hundred measures will contain exactly one thousand grains of water; but for the present process, he found it much more convenient, as well as more conducive to accuracy, to have the instrument of double this capacity, so that the hundred measures will hold two thousand grains of water.

A solution of acetate of lead, which, to avoid repetition of words, will be called the lead test, is spotted over a white porcelain slab, placed conveniently for testing the tin solution during the next operation. It should contain at least one ounce of the acetate to eight ounces of water, and should be rendered clear by filtration. The spots on the slab must be pretty large, in order to insure excess when mixed with the chloride of tin.

The prepared solution of bichromate of potassa is now poured very cautiously into the tin solution, as in the well-known process of alkalimetry, until a drop of the latter, taken out on the end of a glass rod, and applied to the lead test on the slab, gives a faint yellow tinge. The operation is now finished. The number of measures of the chrome liquor consumed is carefully read off, and this number indicates the amount of tin in one hundred parts of the sample.

It may be as well to mention here the effects produced during the foregoing operation. On the first addition of the chrome liquor to the tin solution, sesquichloride of chromium is formed, which gives to the mixture a rich green color; and if, at this stage of the process, a drop be applied to the lead test, a white precipitate of chloride of lead will appear. These effects continue to be produced till all the protochloride of tin is converted into bichloride; but when this result is accomplished, and there is the smallest excess of bichromate of potassa, the lead test gives the yellow chromate of lead, simultaneously with the colorless chloride, and thus communicates the yellow shade, which indicates the completion of the process.

The question may here be raised, whether the indications afforded by a solution of acetate of lead, as applied in the present process, are sufficiently delicate to detect minute quantities of bichromate of potassa; and more particularly when, as in this action, there is such an abundant formation of chloride of chromium, which, by its deep green color, appears so likely to modify, or even disguise altogether, any other tint? This point was examined very minutely: in the first place, the sensitiveness of acetate of lead, spotted on a slab, in detecting bichromate of potassa dissolved in pure water was tried; and it was found that one part of the chrome salt, with ten thousand of water, gave a decidedly yellow coloring to the lead solution; with fifteen thousand of water, the yellow tint was still developed, though very slightly; and with twenty thousand, the tinge was only just perceptible. A solution of pure chloride of chromium was then added to one of the bichromate of potassa, until the mixture had a deep green hue; and after several progressive trials, PENNY was satisfied that the presence of one part of the chrome salt, even when thus colored, may be at once discovered in ten thousand of water.

These results are sufficient to show, that for indicating excess of the chrome liquor, a strong solution of acetate of lead, though used in small drops, and in presence of chloride of chromium, is an extremely delicate test; and that it may, therefore, be with confidence relied on for ordinary practical purposes. It undoubtedly requires a little practice to be able to catch the precise moment when the yellow shade is communicated; but this chemist observed that individuals previously unacquainted with the manipulations of centigrade processes, have no difficulty, after two or three trials, in deciding when the operation of adding the normal chrome solution is completed.

For the sake of convenience, the quantity of the chloride used in each operation has been limited to one hundred grains; but the process obviously possesses the advantage of being executed as easily with five hundred or one thousand, as with one hundred grains In the analysis of commercial products, involving perhaps the valuation of many hundredweights, or even tons, the employment of large quantities is undoubtedly of essential importance; and this is more particularly the case when the processes are intended for the use of practical operators connected with chemical works.

When it is considered desirable to be very exact, PENNY recommends that forty grains of bichromate of potassa, dissolved in water, should be added to the tin solution, and that the alkalimeter should be made up with only ten grains of the chrome salt. The remaining part of the process is conducted according to the directions previously given. By this modification, it is very easy to limit the excess of chrome liquor to half a measure of the alkalimeter, which is equivalent to ·05 grains of the salt.

PENNY further states that he makes use of another test for detecting minute quantities of chromic acid and bichromate of potassa. This consists of sulphocyanide of potassium and pure protosulphate of iron, dissolved together in water, and slightly acidified with hydrochloric acid. A white slab is spotted over with this mixture, and the solution to be tested is brought into contact with it, as when acetate of lead is used. So long as the tin solution contains any protochloride of tin, little or no effect is observable upon the sulphocyanide mixture; but the moment the conversion into bichloride is complete, and there is the least excess of chromic acid in the solution, a dark-brown or red coloring is produced. The depth of the tinge depends entirely on the proportion of chromic acid present. With an extremely minute quantity, the color is brownish; but with a great excess, the tint is blood-red. It is of no consequence if a faint pinkish hue be developed on mixing the solution of sulphate of iron with that of the sulphocyanide, because, when dropped on the slab, this slight coloration becomes scarcely appreciable. This mixture is called the sulphocyanide test, which is an extremely delicate reagent. One part of bichromate in ten thousand is easily discoverable, even when the solution is colored with sesquichloride of chromium; and with pure water, one part in twenty thousand may be detected. Dr. PENNY inclines to give the preference to this test, because the coloration is more distinct, and more easily recognised, than the yellow tinge with acetate of lead; but as considerable nicety is required in the preparation of the sulphocyanide test, he is afraid it will be liable to failure in the hands of inexperienced operators.

He has also used this test very successfully in the estimation of arsenious acid by means of bichromate of potassa; but he reserves a description of its application to this purpose for a future communication.

Single Muriate and Double Muriate of Tin.—In estimating the value of these preparations, he operates somewhat differently from the process described for valuing crystals of tin. Instead of pouring the solution of bichromate of potassa into that of tin, he finds it more convenient to make up an alkalimeter with the tin liquor, and to add this gradually to a known weight of the chrome salt, dissolved in water, until the chromic acid is completely deoxidized. This result is immediately indicated when the mixture ceases to give a red coloration with the sulphocyanide test, or when it no longer produces a yellow tint with acetate of lead. In operating according to this method, it will likewise be noticed, that the gradual changes of color which the solution undergoes during the additions of the tin liquor, indicate with tolerable certainty the approach of the process towards completion. So long as there remains any appreciable quantity of the chrome salt unchanged, the solution has a yellow shade; but when deoxidation is perfect, it becomes of a rich and pure green. The necessary manipulations are as follow:—

Five hundred grains of the sample, whether single or double muriate, are poured into the alkalimeter, and sufficient water added to fill the instrument to 0°, the two liquids being well mixed by agitation.

41·6 grains of bichromate of potassa are dissolved in a basin, with two ounces of warm water and a quarter of an ounce of hydrochloric acid; and into this mixture the tin solution is poured from the alkalimeter, in small successive portions, until, on bringing a drop of it into contact with the sulphocyanide test, previously spotted on a slab, no red or dark color is seen to be produced. The number of measures consumed is read off, and on dividing one thousand by this number, one obtains the proportion of tin in one hundred parts of the sample. In a particular experiment with a specimen of double muriate, of the specific gravity 1·600, he found that, with five hundred grains in the akalimeter, 41·6 grains of the bichromate required thirty-five measures, which gave 28·57 per cent. of tin; with a sample of single muriate, specific gravity 1·422, 47·5 alkalimetrical measures were consumed, equivalent to 21 per cent. of tin.

Great care should be taken that the bichromate of potassa employed in these processes is perfectly pure. As usually sold it is quite unfit for the purpose, in consequence of a large admixture of sulphate of potassa; it may, however, be easily purified by two or three crystallizations; and previous to being used, it should be finely powdered, and heated to incipient fusion.—*Penny.*

The sesquichloride of tin may be prepared by putting into a solution of protochloride of tin a quantity of newly precipitated sesquioxide of iron, when a double decomposition takes place. Two parts of protochloride of tin, and one part of the sesquioxide, give two of protochloride of iron and one of sesquioxide of tin; for example—

$$2\,(Sn\,Cl) + Fe_2\,O_3 = Sn_2\,O_3 + 2\,(Fe\,Cl).$$

This sesquioxide is precipitated, collected, washed free of iron, and then redissolved in hydrochloric acid, forming a sesquisalt of tin. This oxide has several distinctive properties in its reaction with other matters; and in many practical operations in dyeing, it is more than probable that this class of salts plays an important part. It will be seen, under the head IRON in this article, that some of the blues there mentioned are, in all probability, dependent upon the formation of this salt for their peculiar tint.

Persalts of tin are produced by the solution of the binoxide in an acid. The principal acid salt of this sort used in the dye-house is the bichloride. When tin is dissolved in hydrochloric acid, with nitric acid present, and the temperature is allowed to rise, a bichloride will be formed. Dyers, in dissolving for mordants, generally use a mixture of hydrochloric and nitric acids. If care be taken to keep the solution cool, a protochloride is formed, notwithstanding the presence of nitric acid; but should tin be added in too great quantity at a time, the heat will be so much increased by the rapid action that a bichloride will be the result; and there is often produced, in the preparation of these salts, a mixture of protosalts, sesquisalts, and persalts. Hence, says NAPIER, the cause of the irregularity of tint produced by tin mordants thus prepared; and he advises that very great care be taken in the preparation of such salts. Bichloride is often desirable as a mordant, and in that case it may be prepared by dissolving some crystals of the salts of tin, or a quantity of single or double muriate, and passing through the solution a current of chlorine gas—see CHLORINE—or by heating the solution, and adding to it when hot some nitric acid. Care must be taken, in this last process, not to add the acid in too great quantity at a time, as violent effervescence ensues, and the contents will boil over, causing loss. The technical name of the bichloride is *oxychloride.*

The acid preparations of tin used in dyeing are called *spirits,* with a term prefixed to each, denoting their particular application, as red spirits, barwood spirits, plumb spirits, *et cetera.* Their preparation is performed by melting the tin in an iron pot, and pouring the metal from some height into a vessel filled with cold water, which granulates the tin into lamellar masses. This process is termed *feathering* the tin.

Red Spirits are made by mixing together, in a stoneware vessel, three parts by measure of hydrochloric acid, one part nitric acid, and one part water, and adding to this in small quantities at a time feathered tin, till about two ounces of tin to the pound of the acid used is dissolved. In this operation the temperature should not be allowed to rise.

Yellow Spirits are prepared in the same way, the only difference being, that sulphuric acid is used instead of the nitric. This spirit is used for dyeing yellow by bark, as described under QUERCITRON, page 623; but red spirits are equally good for the same purpose. The only advantage of employing the yellow spirit consists in the economy of using sulphuric instead of nitric acid.

Barwood Spirit is prepared by using five measures of hydrochloric acid, one nitric acid, and one water, dissolving in this one ounce of tin for every pound of the whole mixture. One and a half ounce of tin may be used if the red to be dyed be required very deep.—See Barwood, page 572.

Plumb Spirit is prepared by using from six to seven measures of hydrochloric acid to one nitric acid and one water, dissolving in it one and a half ounce of tin for each pound of the acid mixture. This spirit is named from a preparation made with it and a decoction of logwood. A strong solution of that wood is prepared and allowed to cool; after which there is added to each gallon of the solution from a pint to a pint and a half of the spirit; the whole is well stirred and set aside to settle. This preparation has a beautiful violet color; and silk and cotton are dyed of that shade by dipping them into the plumb liquor, without any previous mordant. Of course the depth of tint will correspond to the strength of the solution. Spirit for woollen dyeing is prepared by adding tin to nitric acid, in which a quantity of chloride of ammonium has been dissolved.

All these spirit preparations are varied by different operators, some preferring more or less of the two acids, and also of the tin; but the proportions given form good working spirits, and if care be taken in their preparation not to *fire* them, that is, not to allow the temperature to get so high as to convert the tin into a persalt, the operator will not fail in his processes, as far as the quality of the spirit is concerned.

Acetates and oxalates of tin are also used occasionally for dyeing purposes, by adding a solution of acetate of soda or potassa to chloride of tin for the acetate, and a solution of oxalate of soda or potassa for the oxalate of tin. In both cases a double decomposition takes place, the chlorine combining with the alkali and the acid with the tin. The reactions and precipitates of the acid salts of tin, with other reagents, are as follow:—

	Protosalts.	Persalts.
Potassa and soda,	White, soluble in excess,	White, soluble in excess.
Ammonia,	White, insoluble in excess,	White, soluble in excess.
Carbonate of the alkalies,	White, soluble in caustic alkalies,	White, soluble in caustic alkalics.
Yellow prussiate,	White,	None.
Red prussiate,	White,	None.
Galls,	Slight yellow,	None.
Gold,	Deep purple,	None.
Sulphurets of the alkalies,	Brown,	Yellow, soluble in caustic potassa.

Besides these acid salts of tin just described, there is a series of alkaline salts, in which the binoxide of tin combines with alkalies in the same manner as an acid, and forms definite compounds, named stannates. The stannate of soda has been of late years extensively used as a dyeing agent. The mode of its preparation has been the subject of several patents. The general method is to fuse the oxide of tin with soda, either caustic or carbonate, at a red heat, then dissolving the fused mass in water, and crystallizing. When metallic tin is used instead of oxide, a quantity of nitrate of potassa is put in with the alkali, which by decomposition converts the tin into an oxide. The following extracts from the specification of Mr. James Young's patent, will give a general idea of the methods by which such salts are to be prepared, including stannates and stannites of the alkalies:—

Firstly: To make stannate of soda, he puts a quantity of tin ore, or what is commonly known in Cornwall by the name of *black tin*, reduced to powder, into an iron pot, along with a solution of caustic soda, and sets the pot on a fire to boil. The proportions in which he uses these ingredients vary with their respective qualities. If the ore contain 70 per cent. of tin, he employs about two and a half times its weight of caustic soda liquor, containing about 22 per cent. of soda, increasing or diminishing the proportion of the liquor employed, according as it is desired to produce a stannate with a greater or less excess of alkali. The materials are kept well stirred, and the heat gradually raised up to between 500° and 600° Fahr., at which temperature the ore is acted upon by the soda, and the tin or oxide of tin contained therein, or the greater part thereof, combines with the alkali. The progress of the operation may be known from time to time, by taking out of the pot a small portion of the mass, and ascertaining how much of it dissolves in water, and how much of the ore has been left unacted upon. The hot mass is then transferred from the pot to another vessel, and set to cool. And when cooled it is mixed with water, when any insoluble matters which may have remained in it, unaffected by the caustic soda, are easily separated by filtration or by subsidence. The clear liquor which remains is the stannate required, which may be either employed in that state or evaporated to dryness, or crystallized, the solid salt being dissolved as required for use.

Secondly: This chemist also prepares stannate of soda by mixing a quantity of tin ore, reduced to powder, with one and a half times its weight of nitrate of soda, subjecting the mixture to a red heat in an iron vessel, passing a current of steam over it, and keeping it constantly stirred during the operation, in order to expose fresh portions of it to the action of the steam. Nitric and nitrous acids are given off in fumes, which may be condensed with water, and collected as collateral products—reducing thereby the cost of the stannate. Stannate remains, which may be freed from its insoluble impurities by mixing it with water, and filtration or subsidence, as in the process first before described; and it may be also left either in a state of solution, or crystallized or evaporated, as aforesaid.

Thirdly: He substitutes for the nitrate of soda employed in the last preceding process chloride of sodium —common salt—using, however, equal weights of the salt and tin ore; and pursuing the same method in all other respects, he also obtains thereby stannate of soda, with hydrochloric acid as the collateral product.

Fourthly. He procures by the following process both stannite of soda and stannate of soda. He subjects to a red heat a quantity of metallic tin, mixed with an equal weight of solid hydrate of caustic soda—which may be obtained by boiling down caustic soda liquor, say three and a half hundredweight of the liquor containing 22 per cent. of soda to about one hundredweight of the hydrate—stirring the materials well during the operation; whereupon the water of the hydrate of soda becomes decomposed, and parts with its oxygen to the tin, and the oxide of tin so formed, uniting with the soda, forms a stannite of soda, suitable for some dyeing and printing purposes. To convert this stannite of soda into a stannate of soda, it is boiled in water, on which a portion of metallic tin is precipitated in the form of a black powder, and the solution remaining is stannate of soda. Or, twenty parts of metallic tin are taken, sixteen parts of solid hydrate of caustic soda, and three parts of oxide of manganese, all by weight, and subjected to a red heat in an open pot, keeping the mixture constantly agitated, and allowing a free access of air. So small a portion of oxide of manganese as is contained in this mixture would be quite insufficient of itself to further oxidize all the tin, but this oxide of manganese is converted by the heat and absorption of oxygen from the atmosphere, into a manganate of soda, which salt becomes decomposed by the tin, and part of it goes to form binoxide of tin, leaving a residuum of oxide of manganese; this becomes once more, by a new absorption of atmospheric oxygen, a manganate, which is decomposed by the tin as before, yielding a fresh accession of binoxide of tin; and so the process goes on until all, or nearly all, the tin has become stannic acid and combined with the soda. The mass in the pot is then dissolved in water, and the solution clarified by filtration or subsidence. The supernatant liquid is a solution of stannate of soda, which may be either left as it is, or crystallized, or evaporated to dryness, as aforesaid. The precipitated oxide of manganese may be collected and used over again for the same purpose.

The stannite formed in the first of the processes described under this branch of **Young's** specification, may be changed into stannate of soda by merely keeping it freely exposed, at a red heat, to the atmosphere for a sufficient length of time; but preference is given to manganese as the oxidizing agent, being more expeditious, and, on the whole, cheaper.

Fifthly: He also employs for the formation of stannate of soda, oxide of tin, which is obtained by heating metallic tin to redness in an iron vessel, keeping it well stirred, and passing a current of steam or air over it. And this oxide of tin is treated, along with caustic soda, in precisely the same way as the ore has been before directed to be managed.

Sixthly: Stannate of potassa is manufactured by each and every of the methods before described of manufacturing stannate of soda, substituting only in each case where caustic soda, or nitrate of soda, or chloride of sodium is directed to be employed, an equivalent of caustic potassa, or of nitrate of potassa, or of the chloride of potassium, as the case may be.

Seventhly: This chemist also manufactures stannite of potassa by the same process as stannite of soda as before directed to be produced, substituting for the hydrate of soda an equivalent of hydrate of potassa.—*Young.*

Another preparation of tin with alkalies has been introduced into dyeing operations—a double salt of soda with arsenic and stannic acids, termed arseno-stannate, or arseno-stannite of soda. Reference has already been made by extract from **Napier's** Manual, to the questionable practice of working with such deadly poisons as articles of common use in a factory. And unless applied to some purpose, for which no substitute could be used with anything like the same advantage, their use should be avoided. At all events, a higher motive should exist than mere economy in producing a certain tint upon a dyed or printed article. On the chemical constitution and practical application of this salt, the researches of E. **Haeffely**, read at the meeting of the British Association in Glasgow, in September, 1855, are here quoted:—

By pouring an excess of nitric acid into a solution of stannate of soda and arseniate of soda, in which the arseniate predominates, and bringing this mixture to a state of ebullition, a white gelatinous precipitate is produced, composed of arsenic acid, binoxide of tin, and water; when washed and dried at the ordinary temperature, it forms transparent fragments.

To analyse the above compound, the delicate process described by M. **Levol** was employed, namely, placing within a glass tube heated to redness, one hundred parts in an anhydrous state, and passing through it a current of hydrogen, when the tin is left in the metallic form, and the arsenic is sublimed in the tube.

Three analyses gave:—

Tin, ...	45	.... 46·3	.... 45·21
Arsenic, ...	27·2	.... 26·3	.... —

By adding to these numbers the respective quantities of oxygen required for their maximum oxidation, the formula is arrived at—

$$2\ Sn\ O_2\ As\ O_5,$$

which requires

Tin, ... 44·52 | Arsenic, ... 28·31

Dried in the stove at 248°, the loss amounted to 25·3 per cent., corresponding to 10 equivalents.

To a known weight of a commercial stannate, of a a known quantity of arseniate of soda, boiled with an excess of nitric acid, was added the insoluble arseniate of tin, $2\ Sn\ O_2\ As\ O_5$, and from its weight the amount of arsenic acid and binoxide of tin calculated. The liquid filtrates are then treated with sulphide of hydrogen, to throw down, as sulphide of arsenic, the excess of arsenic acid added intentionally. The amount of arsenic acid found, and the amount added intentionally being known, it will be easy to calculate the original quantity which the stannate contained.

Decomposition of $2\ Sn\ O_2\ As\ O_5 + 10$ aq.—In presence of an excess of a fixed alkali, this arseniate of tin is split into two different soda salts, one of which contains all the arsenic, and crystallizes at first in silky needles, while the mother liquor consists of ordinary stannate of soda; the reaction takes place according to the equation—

$$2\ (2\ Sn\ O_2,\ As\ O_5) + 8\ Na\ O = 2\ (Sn\ O_2\ As\ O_5)\ 6\ Na\ O + 2\ (Na\ O\ Sn\ O_2).$$

This same salt is also obtained by boiling two equivalents of tribasic arseniate of soda with one equivalent of hydrated binoxide of tin. When hydrate of alumina is taken, an arseniate of alumina and soda is obtained.

To analyse the tin salt, each constituent was determined by direct processes. A current of hot air deprived of its carbonic acid, passed over one hundred parts of the salt, gave a loss of 48 per cent. of water. One hundred parts treated with an excess of boiling nitric acid, gave 13·95 parts of the insoluble arseniate of tin, which contained 7·887 parts of binoxide, combined with 6·063 of arsenic acid. One hundred parts acidulated with hydrochloric acid, treated with a current of sulphide of hydrogen, gave 41·5 parts of double sulphide of tin and arsenic.

These two weights being ascertained, a mere calculation may be substituted for the tedious operation of M. LEVOL, for it remains only to calculate the corresponding amount of double sulphides which 13·95 parts of arseniate of tin would form, to be deducted from the total amount of double sulphide, 41·5, obtained; as follows:—13·95 of $2\,Sn\,O_2\,As\,O_5 = 15{\cdot}825 = 2\,Sn\,S_2\,As\,S_5$; and 15·825 $2\,Sn\,S_2\,As\,S_5$, deducted from 41·5 double sulphide, leaves 25·675 of $As\,S_5 = 19{\cdot}05\,As\,O_5$.

By evaporating to dryness the hydrochloric acid filtrates, 37 of chloride of sodium = 19·6 soda are obtained.

Recapitulation of the numbers:—

	At. Weight.	Theory.	Haeffely.
3 Eqs. Binoxide of tin,	93	7·970	7·887
½ Eq. Soda,	37·5	19·766	19·600
1 Eq. Arsenic acid,	115	24·442	25·113
25 Eqs. Water,	225	47·822	48·000
	470·5	100·000	100·600

The formula of this salt is therefore—

$$6\,Sn\,O_2,\ Na\,O,\ 2\,As\,O_5 + 5\,H\,O.$$

Stannate of soda is used as a mordant in print and dye works. Numerous experiments have been made with it on a large scale, to decide whether, in calico printing or dyeing, the hydrated binoxide of tin alone would be preferable to an arseniate of the same oxide as a mordant. The result of comparative trials leads to the preference of hydrated binoxide of tin alone, the various shades being more brilliant and less liable to unevenness than when arsenic acid is present. It would be desirable to substitute, in commerce, a purer stannate of soda for that at present sold, as well as for that containing arseniate of soda.

ZINC.—The only salt of this metal seen in the dye-house is the sulphate—white copperas, or white vitriol—and even this is not used to any great extent, nor for the direct purpose of a dye or mordant, but for certain qualities which the oxide possesses in reacting upon other mordants; and as the precipitate with zinc salts are mostly all white, the sulphate is occasionally used to modify the action of stronger agents, by a double decomposition, where the oxide formed does not affect the tint, as in bichromate of potassa in dyeing yellows. Further, as it parts with a portion of its oxygen when in contact with deoxidizing agents, it is made to serve a purpose in some of the processes in calico-printing. For the chemical character of this metal and its salts, see under article ZINC, in the general arrangement of this work.

PRACTICAL OPERATIONS.—For the substance of the following practical operations of the dye-house, the Editor is greatly indebted to NAPIER'S Manual of Dyeing Receipts.

Decoctions of the different woods are prepared for general use in the dye-house as they are required. If the wood be in the chipped state, it must be boiled for an hour, the proportion used being one pound of wood to the gallon of decoction; a second boiling is generally given with new water, and the liquor obtained used instead of water with more new wood. This second liquor is not good for dyeing alone, but when employed instead of water for new wood, three quarters of a pound per gallon of decoction of the new wood is sufficient. The second liquor may be used, however, as an auxiliary in the dyeing of compound colors, such as browns, drabs, and fawns. If the wood be ground, the same quantity is taken—namely, one pound for each gallon of decoction required, and is prepared as follows:—On a piece of coarse cloth stretched upon a frame or laid into a basket, put the ground wood, and place it over a vessel, then pour over the wood boiling water, until the percolations are nearly colorless.

Barwood and camwood are always used in the ground state, the wood being put into the boiler along with the goods; no decoctions of these woods are made. Decoctions of bark and weld are often formed by putting them into a coarse canvas bag, and then suspending it in boiling water.

To Prepare Annotta.—Into two gallons of water put one pound annotta, four ounces pearl-ash, and two ounces soft soap, and apply heat, and stir until the whole is dissolved. When convenient, it is best to boil the solution.

To Prepare Catechu.—To seven or eight gallons of water put one pound of catechu, and boil till all is dissolved; then add two ounces of sulphate of copper, and stir, when it is ready for use. Nitrate of copper may also be used, taking one wine-glassful of the solution prepared as under:—To one part by measure nitric acid, and two parts water, add metallic copper so long as the acid will dissolve it; then bottle the solution for use.

To Make Sulphate of Indigo.—Into five pounds of the most concentrated sulphuric acid, stir in by degrees one pound of the best indigo finely ground; expose this mixture to a heat of about 160° Fahr. for ten or twelve hours, stirring it occasionally; a little rubbed upon a window pane should assume a purple-blue color.

This preparation is now sold in the market in the state of a paste, under the name of *Indigo Extract*, which is prepared by proceeding exactly as stated for sulphate of indigo, and then diluted with about four gallons of hot water, and the whole put upon a thick woollen filter, over a large vessel, and hot water poured upon the filter, until it passes through nearly colorless; the blackish matter retained upon the filter is thrown away, and the solution passed through is transferred to a leaden vessel, and evaporated to about three gallons, to which is added about four pounds chloride of sodium, and well stirred; the whole is again put upon a woollen filter, and allowed to drain. The extract remains as a thin pasty mass upon the filter, and is ready for use.

To Make Red Liquor.—Into one gallon hot water place two pounds of alum; dissolve, in a separate vessel, two pounds acetate of lead in one gallon water;

in a third vessel dissolve half a pound crystallized soda; mix all the solutions together, and stir well for some time, then allow to stand overnight; decant the clear solution, which is ready for use.

Other proportions for making this mordant are given at page 37.

To Make Caustic Potassa.—To three gallons of water add two pounds either black or pearl ashes, and boil; when seething, add newly-slaked lime, until a small quantity taken out does not effervesce when an acid is added to it. To do this, take a tumbler half-filled with cold water, take out a table-spoonful of the boiling lie, and put into the tumbler, and add a few drops of sulphuric acid; were sulphuric acid added to the hot lie, it would spurt up and endanger the operator. When the addition of acid causes no effervescence, the boiling and adding of lime is stopped, and the whole allowed to settle; then remove the clear into a vessel having a cover, to prevent it taking carbonic acid from the air. This serves as a stock for general use. The lime sediment remaining may have some hot water added, which will give a strong lie, and may be used for first boils for yarn or heavy cloth.

To Make Caustic Soda.—For every gallon of water add one pound of soda ash, or two pounds of crystallized soda of the shops; boil, and proceed by adding slaked lime, and testing as for potassa; boiling for some time is essential to insure causticity.

To Make Lime-Water.—Take some well and newly-burned limestone, and pour over it some water so long as the stone seems to absorb it, and allow it to stand; if not breaking down freely, sprinkle a little more water over it. A small quantity is best done in a vessel, as an old cask, in which case it may be covered with a board or bag. After being slaked, add about one pound of this to every ten gallons of cold water, then stir well and allow to settle; the clear liquor is what is used for dyeing. This should be made up just previous to using, as lime-water standing attracts carbonic acid from the air, which tends to weaken the solution.

To Make Bleaching Liquor.—Take a quantity of bleaching powder, and add to it as much water as will make it into a thin cream; take a flat piece of wood, and break all the small pieces by pressing them against the side of the vessel, then add two gallons of cold water for every pound of powder; stir well, put a cover upon the vessel, and allow the whole to settle. This will form a sort of stock vat for bleaching operations.

To Make a Sour.—To every gallon of water add one gill of sulphuric acid, stir thoroughly; goods steeped in this should be covered with the liquor, as pieces exposed become dry, which deteriorates the fibre; if left under the liquor, the cloth is not hurt by being long in the sour; but on being taken out every care should be taken to wash out the liquor thoroughly, otherwise the goods will be made tender.

To Make Cochineal Liquor or Paste.—Put eight ounces ground cochineal into a bottle, and add to it eight ounces, by measure, ammonia, and eight ounces water; let the whole simmer together for a few hours, when the liquor is ready for use.

To Make Iron Liquor.—See *Acetate of Iron*, page 42; or small quantities may be made as follows:—Put pieces of iron, or filings, into pyroligneous acid, and allow it to stand for several days, stirring occasionally; a gentle heat assists the action.

To Make up a Blue Vat.—Take one pound of indigo, and grind in water until no grittiness can be felt between the fingers; put this into a deep vessel—casks are generally used—with about twelve gallons of water; then add two pounds copperas, and three pounds newly-slaked lime, and stir for fifteen minutes; stir again after two hours, and repeat every two hours for five or six times; towards the end, the liquor should be of a greenish-yellow color, with blackish veins through it, and a rich froth of indigo on the surface. After standing eight hours to settle, the vat is fit to use.

To Make Spirits or Tin Preparations.—On this subject, see *Tin*, in the present article, page 653.

For Copperas.—See *Iron Salts*, page 646.

For Blue-Stone—sulphate of copper.—See *Copper Salts*, page 555.

In making solutions of these salts, such as copperas, blue-stone, chrome, *et cetera*, there is no fixed rule to be followed A quantity of the crystals are put into a vessel, and boiling water poured upon them, and stirred till dissolved. Some salts require more water than others when saturated solutions are wanted; but in the dye-house a certain degree of saturation is not essential, and therefore there is always used ample water to dissolve the salt. In all cases, however, the proportions are known, so that the operator, when adding a gallon or any quantity of liquor to the dye bath, knows how much salt that portion contains. From half a pound to one pound per gallon is a common quantity.

To Remove Oil Stains.—When oil spots are upon goods, and so fixed or dried in, that steeping in an alkaline lie will not remove them, rub a little soft soap upon the oil stain, and let it remain for an hour, then rub gently with the hand in a lather of soap, slightly warmed, and then wash in water; for cotton, a little caustic lie will do equally well for removing the oil, but the soap is the preferable process, and seldom fails. It is essential that all oil or grease be removed before dyeing.

To Remove Iron Stains.—Take a little hydrochloric acid in a basin or saucer, and make it slightly warm, then dip the iron stain into the acid for about one minute, which will dissolve the oxide of iron; the cloth must be well washed from this, first in water, then in a little soda and water, so as to remove all trace of acid. A little oxalic acid may be used instead of hydrochloric, but more time is required, and with old fixed spots is not so effective. The same precautions are necessary in washing out the acid, as oxalic acid dried in the cloth injures it.

To Remove Mildew from Cotton.—Proceed with the stains by rubbing in soap or steeping in a little soda, washing, and then steeping in bleaching liquor same as in the process of bleaching, or by putting a wine-glassful of the stock liquor as prepared above in one pint of water, afterwards wash, and pass through a sour, and wash.

To Remove Indelible Ink Marks.—Steep the marking in a little chlorine water, or a weak solution of bleaching liquor, for about half an hour, then wash in ammonia water, which will obliterate the stain; the goods to be washed from this in clean water. Or they may also be removed by spreading the cloth with the ink mark over a basin filled with hot water, then moisten the ink mark with the tincture of iodine, and immediately after take a feather and moisten the parts stained by the iodine, with a solution of hyposulphite of soda, or caustic potassa or soda, until the color is removed, then let the cloth dip into the hot water; after a while wash well, and dry.

To Detect Animal and Vegetal Fibres.—Treat the fabric with bichloride of tin heated to from 130° to 150° Fahr., when the cotton and linen become black, and wool and silk remain unchanged.

To Detect Mixed Fabrics of Cotton and Wool.—Dip a piece of the suspected cloth in bleaching liquor; after a little the woollen turns yellow and the cotton white, and consequently may be easily distinguished.

To Detect Cotton in Linen.—The piece to be tested is boiled to remove all dressing, and then dried; a portion of the piece is put into common vitriol for about one minute, it is then taken out, washed in water several times, and then in a weak solution of soda or potash, and all gummy matter formed is removed by gentle rubbing; by this process the cotton is dissolved out and the linen remains, or what portion of the cotton is not dissolved becomes opaque white, the linen is transparent, and is thus easily detected. By comparing the portion of cloth immersed with a similar portion not tried, the quantity of cotton present may easily be estimated.

Another method for Detecting Cotton in Linen.—Take a small piece of the cloth, boil in water and dry; then take three parts, by weight, of sulphuric acid, and two parts of crushed nitrate of potassa; the dry piece of cloth is put into this for six or seven minutes, and then washed from this till there is no taste of acid; dry at a gentle heat; then put it into a mixture of ether and alcohol, which will dissolve the cotton and not the linen. If the piece be weighed before putting into the ether and alcohol, and after, the quantity of cotton in the fabric may be thus ascertained.

Cotton and Wool.—Take a small piece of the cloth and boil in caustic soda, when the wool will be dissolved and the cotton remain. If the threads have been previously counted, their relative mixture may be thus ascertained.

Cotton with Silk and Wool.—Put a piece of the cloth into chlorine water or bleaching liquor. The cotton is whitened by the liquor, and the silk and woollen become yellow. These changes will be easily distinguished by the use of a small pocket lens.

Another method.—Take a small piece and unravel the threads, and inflame them; the cotton burns away freely, with little or no black charcoal; the woollen and silk shrivel up, leave a black charcoal, and give a strong smell.

To prepare Cotton Yarn for Dyeing.—Cotton is generally brought to the dye-house in bundles of five pounds or ten pounds, made up of *heads*, each head having ten hanks, except when the yarn is very coarse, when each head has only six hanks; or very fine, when each head has twenty hanks. The number of heads indicates the grist of the thread, called *the number*. Thus, ten pounds of No. 60 will have sixty heads of ten hanks, or thirty heads of twenty hanks. These heads are made up into spindles of eighteen hanks by the dyer, and through each spindle is tied a piece of stout thread or twine, termed a band; the bundle, when banded, is divided into four or six quantities, and rolled up and tied into bundles for boiling. Thus, No. 60 will give thirty-five spindles and twelve hanks, equal to thirty-six, and will be rolled up into six sixes, or all sixes, as it is termed, or four nines, ten pounds being invariably named a bundle.

After banding, cotton is boiled in water for two or three hours until thoroughly wet. The bundles are then loosed, and each roll of yarn is put upon a wooden pin, about three feet in length and about one and a half inch thick, six pins or sticks forming a bundle, or four sticks, according to the division made by the bander.

If the color to be dyed be dark—such as brown, black, orange, deep blue, *et cetera*—the yarn is now ready for the dyeing operation; but if for light shades—such as pink, sky-blue, *et cetera*—the yarn must be bleached previous to being dyed, which is done thus:—

A vessel sufficiently large to allow of the cotton being wrought in it freely without pressing, is to be filled about two-thirds with boiling water; add a pint of bleaching liquor from the solution made up as described above for every gallon of water in the vessel, then work the yarn in this for half an hour. Into another vessel of similar size, filled two-thirds with cold water, add a wine-glassful of sulphuric acid for every two gallons of water; stir well, and then put the yarn from the bleaching solution into this and work ten minutes, and then wash from this until all acid is removed.

This, in general, will produce a white of sufficient purity for all light shades.

But if the cotton has to be finished white, in that case the process is conducted as under:—

The yarn when banded is boiled for three hours in caustic lie, either potassa or soda, made by adding one gill of the caustic lie, prepared as described above, for each gallon of water in the boiler; wash well from this lie, and lay the yarn to steep in a bleaching liquor, made up as in last receipt, but with cold water; after four or five hours, lift and steep for an hour in a sour of one wine-glassful of vitriol to the gallon water, lift and wash well, then boil again in a lie of half the strength of the first for two hours, and wash from this, and steep again four hours in bleaching liquor; wash from this, and steep for an hour in a clean sour; wash well from this, and dry. A little smalt blue is put into the last washing water to clear the white.

To prepare Cotton Cloth for Dyeing.—The cloth is taken out of the fold and hanked up by the hand, taking the end through the hank and tying it loosely, technically termed *kinching;* it is then steeped in old alkaline lie overnight, which loosens and removes the oil, grease, and dressing which it has obtained in weaving; it is then thoroughly affused in clean water. Where there is a dash wheel, it should be used for this washing.

From these liquors often fermenting with the paste in the cloth, this process has been technically termed the *rot steep.*

If the colors required upon the goods be dark, no other preparation is necessary; but if light, the cloth has to be bleached, which is done by boiling after the *rot steep* in caustic lie, of the strength of one gill of stock lie to the gallon of water, for three hours; wash out the boil, and steep in bleaching liquor for six hours, same strength as given for yarn; wash, and steep an hour in a strong sour of one wine-glassful of sulphuric acid to the gallon of water; wash well from this before drying or dyeing. If the cloth be very heavy, one operation may not be enough; in such cases proceed as at the beginning, by boiling, steeping, and souring. In bleaching cloth for dyeing, care has to be taken that it is all equally white, otherwise it will show in the color.

If the goods be old, and have been previously dyed, and if the shade required be a deep shade, and the color of the goods light, in that case nothing is generally required but steeping to remove any grease or starch; but if the dye upon the cloth be dark, the best method is to proceed as if they were grey goods, and subject them to a process of bleaching. The quantity of water used in the operation is simply as much as will allow the pieces or the yarn ample room to be put under the fluid easily without pressure.

RECEIPTS.—In the following receipts, the quantity of stuffs given is for ten pounds of cotton, whether yarn or cloth. Of course any quantity may be dyed by proportioning the dyeing materials to the fabric; but when small articles are dyed—such as ribbons, gloves, handkerchiefs, or a dress—a little more of the stuff may be used without affecting the general tint of the color, as small quantities cannot be dyed with the same economy as on the large scale. Where washing is referred to, it is always in cold water, unless hot be mentioned.

1. *Common Black.*—Steep the goods in a decoction of three pounds sumach while it is hot, and let them lie overnight; wring out and work for ten minutes through lime-water, then work for half an hour in a solution of two pounds copperas. They may either be washed from this, or wrought again through lime-water for ten minutes—the former gives the preferable shade, but must be well affused; work them for half an hour in a warm decoction of three pounds logwood, adding a half-pint of chamber lie; before entering the goods, lift and raise with two ounces of copperas in solution; work ten minutes, then wash and dry.

2. *Jet Black.*—The goods are proceeded with exactly as last; but along with the logwood is added one pound fustic, and finished as above.

In both these blacks, if three pints iron liquor be used instead of the copperas, or in part mixed with the copperas, it makes a richer shade of black, but copperas is most generally used; if mixed, use half the quantity of each.

3. *Blue Black.*—Dye the goods first a good shade of blue by the vat, and then proceed exactly as for common black; but should the blue be very deep, as is often the case, then half the quantity of the materials given above will suffice.

4. *Spirit Brown.*—The goods are dyed first a spirit yellow, exactly as at page 623, and washed; they are then wrought for half an hour in a decoction of two pounds lima or peach wood and one pound logwood; lift up and add three ounces of alum in solution, and work fifteen minutes; wash and dry. By varying the proportions of logwood and limawood, a variety of shades can be produced.

5. *Mordant Brown.*—Dye a yellow, the same as at page 624, then work for half an hour through a decoction of two pounds limawood and eight ounces logwood, lift and raise with two ounces alum in solution· work for fifteen minutes, and wash and dry.

This method is well adapted for cloth goods, is better than the spirits, and more easily performed by the non-practical man. The spirit brown is best for yarn.

6. *Cinnamon Brown.*—Dye a dark spirit-yellow, the same as at page 623, and work for twenty minutes in three pounds and a half limawood and half a pound logwood; then raise, by adding two ounces of alum in solution; wash in cold water, and dry.

7. *Uvanterin Brown.*—Dye a spirit-yellow, the same as at page 623, and then work for twenty minutes in a decoction of one pound limawood and one pound fustic; lift and raise, by adding half-pint red liquor, as at page 656; work ten minutes in this; wash in cold water, and dry.

8. *Fawn Brown.*—Take one part annotta liquor—page 656—and one part boiling water; stir well, and work the goods in this for ten minutes; wring out and wash in two waters; then work for twenty minutes in a decoction of two pounds fustic and one pound sumach; lift and add three ounces copperas in solution; stir well, and work for twenty minutes longer; wash from this in two waters; then work for twenty minutes in a decoction of eight ounces limawood, eight ounces fustic, and four ounces logwood; lift, and raise with one ounce alum; work ten minutes; wring out, and dry.

9. *Catechu Brown.*—Work the goods at a boiling heat for two hours, or steep for several hours if the liquor is allowed to cool, in two pounds catechu, prepared as at page 656; wring out, and then work for half an hour in a hot solution of six ounces bichromate of potassa; wash from this in hot water. If a little soap be added to the washing water, the color is improved.

Any depth of shade of brown may be dyed by repeating the operation.

10. *Catechu Chocolates.*—Dye a brown, as last, then work fifteen minutes in a decoction of one and a half pounds logwood; lift, and add three ounces alum in solution; work ten minutes longer; wash out, and dry.

By this process, a great variety of browns and chocolates may be produced, both by using different quantities of logwood, and by different depths of brown before the logwood is applied.

11. *Chocolate or French Brown.*—Dye a spirit-yellow, as at page 623, then work for half an hour in a decoction of three pounds logwood; lift, and raise with half a pint of red liquor, and work ten minutes longer; wash and dry.

Another shade of deeper chocolate will be obtained by adding one pound fustic with the logwood.

12. *Catechu Fawns.*—Work the goods fifteen minutes in hot water, to which has been added two pints of the catechu—page 656; wring from this, and work fifteen minutes in hot water, in which has been dissolved one ounce of bichromate of potassa; wash from this, and dry.

13. *Catechu Fawns—Another method.*—Work in the solution of catechu the same as last; wring out, and then work for fifteen minutes in warm water, to which has been added two ounces acetate of lead previously dissolved; wash in cold water, and dry.

14. *Catechu Fawns—Another method.*—Work for fifteen minutes in warm water, to which has been added four pints of catechu—page 656; lift, and add two ounces copperas in solution, and work for other fifteen minutes; wash from this in one tub water, and finish through warm water, in which as much soap has been dissolved as will raise a lather, and dry out.

For *Pinks*, *Roses*, *et cetera*, see SAFFLOWER, p. 626.

15. *Common Red.*—Put the goods into a decoction of three pounds sumach as soon as possible after being made, and let them steep till the liquor is cold, say overnight; wring out, and work for an hour in red spirits diluted to from 2° to 2·5° Twaddle's hydrometer, or about one gill spirits, page 653, to each gallon water; wring out, and wash well, and make a decoction of three pounds limawood and one pound fustic; work the goods in this for half an hour at a heat that the hand may be held in without pain, lift up and raise by adding one gill red spirits; return the goods, and work fifteen minutes longer; wash out, and dry.

16. *Barwood Red.*—To a decoction of two pounds sumach add a wine-glassful of vitriol, and steep the goods in this decoction for at least six hours; wring out and work in spirits, diluted to 2·5° Twaddle, for an hour; wring out and wash, then pass through a tub of warm water; put ten pounds of barwood into a boiler with water, and bring it near to the boil, into which the goods are entered and wrought amongst the wood grains for about three quarters of an hour; lift out, wash, wring, and dry. Deeper shades may be dyed by using greater quantities of stuffs in each operation.

17. *Common Crimson.*—To a decoction of three pounds sumach, the goods steeped in it overnight, and then spirited at 2° Twaddle; wash and work through a decoction of three pounds limawood and one pound logwood for thirty minutes, then raise with a gill of red spirits; work for fifteen minutes more; wash out, and finish.

By using only limawood without logwood, a beautiful red crimson is obtained, and by varying the proportions and quantities, a great diversity of tints will be dyed by the same proportion of sumach and spirits.

18. *Light Straw.*—To a tub of cold water add four ounces of acetate of lead, previously dissolved, work the goods through this for fifteen minutes, and wring out; into another tub of water add two ounces of bichromate of potassa; work the goods through this ten minutes, wring out, and pass again through the lead solution for ten minutes; wash, and dry.

19. *Leghorn.*—Proceed and finish exactly as last, but along with the chrome add a half-pint annotta liquor.

Different depths and tints may be obtained by using more or less of these stuffs, without varying the mode of working.

Other receipts are given for dyeing chrome yellows, oranges, *et cetera*, at page 644.

20. *Annotta Orange.*—Heat the annotta solution—page 656—to working heat—about 140° Fahr.; work the goods in this for twenty minutes; wring tightly out, in order not to lose much stuff; wash in a couple of waters, and dry.

If this color is passed through water made to taste sour by an acid, a very red orange, bordering on scarlet, is produced; but the hue is very fugitive.

Blues of different sorts are given at pages 647, 648.

21. *Logwood Blue.*—Dye first a light-blue with the vat, then lay in a hot decoction of two pounds sumach for several hours, and keep working for fifteen minutes through water, to which has been added one pint acetate of alumina—red liquor,—and one pint acetate of iron—iron liquor; wash from this in two tubfuls of hot water, then work twenty minutes in a decoction of two pounds logwood; lift, and raise with half a pint of red liquor; work ten minutes longer; wash, and dry.

22. *Fustic Green on Yarn.*—Dye a vat blue, wash and wring, and then pass through the acetate of alumina at 6° Twaddle; wash through a tub of hot water, and then work for twenty minutes in a decoction of four pounds fustic; lift and raise with two ounces alum in solution, work fifteen minutes, wash, and dry.

23. *Bark Green on Cloth.*—The goods after being cleaned, not bleached, are wrought for ten minutes in red liquor at 7° Twaddle, wrung out, and passed through a tub of hot water, and then wrought for half an hour in a decoction of three pounds bark, lifted and raised with half a pint red liquor, and wrought ten minutes longer, then lifted and drained. Into a tub of cold water add five gallons of chemic—neutralized sulphate of indigo—page 624; work the yellow in this for twenty minutes, wring out, and dry. Of course any depth of shade may be made in this way by varying the quantity of stuff used.

24. *Fustic Green on Cloth.*—Work the goods in acetate alumina at 6° Twaddle, and dry in a stove or hot chamber; then wet out in hot water, and work for twenty minutes through a decoction of three pounds fustic; lift, and raise with two ounces alum in solution; work fifteen minutes; wring out, and then work in the chemic prepared as in page 624; wring out, and dry.

25. *Green with Prussian Blue.*—Dye a good prussian blue, same way as sky—page 647—according to the depth of green required; and then work ten minutes in acetate of alumina at 6° Twaddle; wash in a tubful of warm water, and work for half an hour in a decoction of three pounds fustic; lift, and raise with two ounces of alum in solution; work ten minutes longer; wash, and dry.

Bark may be substituted for fustic in this green. If so, the bark should not be wrought very warm; and thus a finer tint is obtainable.

26. *Sage Green.*—Dye a prussian blue, same as sky—page 647—and work ten minutes in a solution of two pounds alum; wring out, and work fifteen minutes in a decoction of one pound fustic; lift, and add a pint of the alum solution formerly used; work ten minutes, and then wash and dry.

27. *Olive or Bottle Green.*—Dye a good shade of prussian blue—page 647—then mordant by working ten minutes in acetate of alumina at 7° Twaddle; wring out, and wash in hot water; work for half an hour in a decoction of three pounds of fustic and one pound of sumach; then add half a pint iron liquor,

and work fifteen minutes; then wash in one tub water having two ounces alum dissolved in it, and dry.

28. *Olive or Bottle Green—Another method.*—Work the goods in red liquor at 7° Twaddle, wash in warm water, and work half an hour in a decoction of three pounds bark and one pound sumach; lift, and add half a pint iron liquor, work other fifteen minutes; wring out, and then work fifteen minutes in the chemic—page 624; wring out of this, and dry.

29. *Olive Green.*—Dye a prussian blue—page 647—then work for ten minutes in red liquor at 6° Twaddle; wash in hot water, and work in a decoction of three pounds bark and one pound logwood; lift, and raise with half a pint of red liquor, and work ten minutes; wash from this, and dry.

A great variety of shades of green may be obtained by varying the proportions of bark and logwood. Fustic may also be used instead of bark.

If the goods be yarn, a light vat blue may be dyed instead of the prussian blue, and proceeded with afterwards in the same manner as above.

Other shades and qualities of green are given at page 644.

30. *Puce or Lilac.*—Work for an hour in red spirits, made down to 2° Twaddle; wring out, and wash, then work half an hour in a decoction of three pounds of logwood at working temperature, about 140° Fahr.; lift up, and add one gill red spirits, work for twenty minutes; wash from this, and dry. Half a pint of red liquor, or two ounces alum, may be added to the logwood as raising, instead of red spirits.

31. *Another method.*—Work the goods for fifteen minutes in red liquor at 7° Twaddle; wring out, and wash in one tub warm water, then work half an hour in a decoction of two pounds of logwood at working heat; lift, and raise with half a pint red liquor, or two ounces alum; work ten minutes in this, and wash in a tub of lukewarm water; wring out, and dry.

32. *Light-Purple or Adelaide.*—The goods are laid in a decoction of two pounds sumach, wrung out, and wrought half an hour through the spirit plumb—page 654; wring out, and wash in clean cold water till no taste of acid is felt on the goods, and dry.

When working with the spirit plumb, it is best to take the plumb liquor into a tub or separate vessel, and work the goods in this, returning the liquor afterwards to the plumb tub.

33. *Another method.*—The goods are laid in two pounds sumach, wrung out, and wrought for twenty minutes in red spirits at 2° Twaddle; wash well from this, then work in the spirit plumb in the same manner as last; wash out till no taste of acid is on the goods, and dry.

34. *Purple.*—Steep in two pounds of sumach till cool; work in red spirits at 2° Twaddle for an hour, and wash in cold water; then work for half an hour in a decoction of three pounds of logwood at working heat; then lift, and add one gill of red spirits, and work for ten minutes more; wash in cold water, and dry.

A variety of purple shades may be dyed by this process, by slightly varying the proportions of the stuffs. If a browner tint is required, give a little more sumach; if a bluer tint, less sumach, and increase the logwood, and raise with half a pint red liquor, or two ounces alum, instead of red spirits.

35. *Lavender or Peach.*—Work the goods for twenty minutes through the spirit plumb, wring out, and wash in clean cold water till no taste of acid is perceived, and dry.

36. *Logwood Lilac or Puce.*—Dye the goods a good shade of prussian blue—page 647—then work for fifteen minutes in a decoction of one pound of logwood at working temperature; lift up, and add four ounces alum; work ten minutes, and then wash in cold water, and dry.

37. *Another method.*—Dye a sky-blue—page 647—then, in a tub of warm water, add one gallon alum plumb—page 642—and work in this fifteen minutes; wring out, and dry.

38. *Safflower Lavender.*—Dye the goods a sky-blue—page 647—then dye a safflower pink on the top of the blue, with one pound safflower; but in dyeing the pink, the sulphuric acid must be added to the safflower liquor previous to the blue being entered into it, otherwise the alkali of the safflower will destroy the blue.

One need hardly add, that different depths of color, and different hues, will be obtained by varying the shade of blue and the quantity of safflower. Deep blue and little safflower give a lilac, or puce; while a light-blue, with four pounds of safflower, will give a peach color.

39. *Safflower Lavender—Another method.*—Dye a pink with two pounds of safflower—page 626—then proceed and dye a sky-blue over this—page 647—and finish exactly as described for sky-blue.

Of course the remarks made on last receipt, in reference to different shades, apply equally to this method; but more safflower is required by this method than the other.

40. *Common Drab.*—Work the goods for fifteen minutes in a decoction of half a pound sumach; lift, and add one ounce copperas in solution, and work for fifteen minutes; wash out in a tub of cold water, then work for fifteen minutes in a decoction of four ounces fustic, two ounces limawood, and one ounce logwood; lift, and raise with one ounce alum in solution; work ten minutes longer, wring out, and dry.

A great variety of shades can be produced by this means, varying the proportion of the limawood, fustic, and logwood; and different depths, by varying the quantities of sumach and copperas.

41. *Olive Drab.*—Work fifteen minutes in half a pound sumach, then add one ounce copperas, and work in this for fifteen minutes; wash in one tub water, and work in half a pound fustic for twenty minutes, and raise with one ounce alum; work ten minutes, and dry out.

42. *Drab.*—To a tub of hot water add one pint of annotta—page 656—which gives a light salmon color, then proceed with this exactly as last for olive drab; or, by varying the quantities in last operations, a great variety of drabs may be dyed.

43. *Stone Color.*—Work the goods twenty minutes in a decoction of one pound sumach; lift, and add one ounce copperas in solution; work fifteen minutes, and

wash in one tub cold water; then work ten minutes in warm water, to which half a pint alum plumb—page 642—has been added; wring, and dry.

This gives a reddish tint; but if this tint be not required, the alum plumb may be dispensed with, using half an ounce alum in the water.

44. *Catechu Stone Drab.*—Work the goods for fifteen minutes in two pints catechu—page 656—in hot water; lift, and add two ounces copperas in solution; work for fifteen minutes, and wash in one tub of water. Into another tub of warm water, add a decoction of two ounces logwood; work the goods in this for ten minutes; lift, and raise with half an ounce alum; work ten minutes longer, wring out, and dry.

45. *Catechu Drab.*—Work the goods for fifteen minutes in hot water, to which has been added one pint catechu—page 656—then lift, and add one ounce copperas; work ten minutes, and wash out and dry.

A variety of tints may be obtained by *topping* with a little different woods.

PREPARING AND DYEING OF SILK.—Silk is also banded in the same manner as cotton, using no particular number of hanks, but in quantities convenient for making up into skeins when finished. After banding, it is carefully tied up and put into fine canvas bags, and seethed in these in a strong solution of soap for three or four hours, until all the gum is boiled off. If the silk be yellow gum, it is put upon sticks like the cotton, and wrought in a solution of soft soap, at a temperature just approaching the point of ebullition, for about one hour, when it is tied up as the white gum silk, and put into bags and boiled till all the gum is removed; when boiled, it is washed from the soap, and *sticked* for dyeing, putting six or eight heads of silk on each stick. This is all that new silk requires before dyeing, but a great portion of the dyeing required by the amateur is re-dyeing, such as ribbons, handkerchiefs, dresses, shawls, *et cetera.* The first operation with goods to be re-dyed is steeping in a strong saponaceous solution at nearly 212° for a few hours, in order to remove stains of oil or grease; they are afterwards washed in water, and if the color remaining upon them after this operation be light and equal, and the color wanted be dark, then no more is required; but if unequal, they should be put into a sour—page 657—for fifteen minutes, then washed out, and proceeded with for the tint required.

The quantities of dyestuffs given in the receipts that follow, are for dyeing five pounds weight of silk. In cases where the silk is very hard spun, as in some ribbons and dresses, a little more dyestuff may be used than the quantities given, and also a little more time. Some kinds of goods will be bulkier than others of the same weight; in such cases, less or more water may be used accordingly. The quantity of water must always be sufficient to allow the goods to be quite loose when immersed under the surface.

When goods are washed from the dye, it is always in cold water, except otherwise mentioned in the prescription.

1 *Black.*—Work for an hour in a solution of eight ounces of copperas, and wash well out in cold water; then work an hour in a decoction of four pounds of logwood, adding to it half a pint of urine; lift out, and add to the logwood liquor two ounces copperas in solution; work fifteen minutes, wash, and dry.

This will give a good black, not very deep. If a deep black is required, add to the copperas solution two ounces, by measure, nitrate of iron; indeed, for re-dyes, it will be better to add this at all times. If a blue shade is desired, instead of adding urine, dissolve a little white soap in the logwood liquor, and add no copperas.

2. *Full Deep Black.*—Work an hour in one pound copperas and two ounces nitrate of iron, wash and work for an hour in a decoction of five pounds logwood and one pound fustic; lift, and add two ounces copperas, work ten minutes; wash, and finish.

If the color is not deep enough, add a little more logwood before raising with the copperas.

3. *French Black.*—Work an hour in one pound copperas and four ounces alum; wash well, and then work an hour in a decoction of four pounds logwood, in which a little white soap has been added; wash out, and finish.

4. *Blue Black by Prussiate.*—Dye a deep prussian blue as described—page 648—and work from the prussiate for half an hour in eight ounces copperas; wash well from this in cold water, and then work for half an hour in a decoction of two pounds logwood, using neither urine nor soap in it; lift, and add a little of the copperas solution with which the goods were mordanted; work other ten minutes, then wash and dry.

5. *Deep Hat Black.*—Work the silk fifteen minutes in a decoction of two pounds fustic and one pound bark; lift, and add in solution six ounces acetate of copper and six ounces copperas; work other fifteen minutes, and then sink the whole under the surface, and let it steep for several hours, say overnight; lift and wash from this, then make a decoction of five pounds logwood; dissolve in it as much white soap as will make a lather, and work in this for an hour; wash out, and dry.

6. *Brown.*—Dye an orange with annotta—see *Orange,* page 660; then work for fifteen minutes in a solution of eight ounces copperas; wash from this in two waters, and then work half an hour in a decoction of three pounds fustic, eight ounces logwood, and one pint archil liquor; lift, and add half a pint alum solution; work ten minutes, wash and dry.

One pound of brazil or peachwood may be substituted for the archil liquor, with nearly the same results. A variety of this shade of brown may be dyed by varying the quantity of each stuff.

7. *Brown.*—Dye an orange by annotta—see *Orange;* page 660; and then work for twenty minutes in a decoction of three pounds fustic, eight ounces sumach, eight ounces peachwood; lift up, and add three ounces of copperas in solution; work other fifteen minutes, wash out in two waters, using half a pint of alum solution in the last water.

If the particular tint required is not obtained by the above proportions, it may be given in the water with the alum, using it a little warm. If yellowness is required, add fustic. If redness is wanted, add peachwood. If depth or blueness, add logwood.

A great many particular hues of brown may be dyed by this method; as, for instance, by using only fustic and sumach in the second operation, a California brown is obtained, *et cetera*, as just referred to, so that any intelligent person will easily regulate his colors and tints.

8. *Red Browns.*—Dye a deep orange by annotta—see *Orange*, page 660; then work for fifteen minutes through the spirit plumb liquor—page 654—wash well, and dry.

Particular tints may be given by adding either logwood, peachwood, or fustic in the last washings, as described in last receipt.

9. *Another method.*—Steep the silk in an alum solution of eight ounces to the gallon for an hour, and wash out in warm water; then work half an hour in a decoction of one and a half pound fustic, one and a half pound peachwood, eight ounces logwood; lift, and add one pint of the alum solution, work for ten minutes; wash and dry.

10. *Chocolate Brown.*—Steep the silk for an hour in alum, one pound to the gallon of water; wash once in warm water, and then work for half an hour in a decoction of three pounds peachwood and one pound logwood; lift, and add one pint of the alum solution; work in this for fifteen minutes; wash out, and dry.

Deeper shades of chocolate are obtained by using a smaller quantity of peachwood and more logwood, in equal proportions. A little fustic, say four ounces, may be added, which will give a still deeper hue if required.

11. *Bronze Brown.*—Work for half an hour in a decoction of eight ounces fustic, to which four ounces, by measure, of archil liquor has been added; then lift, and add two ounces of the solution of copperas; work fifteen minutes, wash in cold water, and finish.

12. *Pink.*—Prepare the safflower as described—page 625; then take a quantity of solution equal to one pound of safflower originally used; add to this solution one ounce, by measure, of sulphuric acid; enter the silk, and work for half an hour; then wash in a vessel with warm water in which about one ounce cream tartar has been dissolved; wring out, and finish. Lighter or darker shades may be dyed by using less or more safflower; when more is used, a little more time will be required.

If safflower extract be used, which is simply the red coloring matter—carthamin—precipitated by an acid, add about a pint of the extract to warm water, with half a wine-glassful of sulphuric acid; stir well; work the goods in this, and proceed as above.

For other shades with safflower, as rose, crimson, *et cetera*, see page 626.

13. *Cochineal Crimson.*—To every gallon of water used, add about two ounces, by measure, bichloride of tin—page 653; allow any sediment to settle, and take the clear solution, and apply heat; when warm, work the goods in it for an hour or more.

Boil in a bag two pounds of cochineal, by suspending it on the surface of the water for half an hour; add this to the proper quantity of water for working the goods, the whole being at hand heat; wring the silk from the spirits, and work it in this cochineal solution for half an hour, when it is let steep for several hours, keeping well under the liquor; wash well out of this in cold water. If the shade is not blue enough, a little cochineal dissolved in ammonia may be added to the water; and after working in this for ten minutes, wring out, and dry.

14. *Common Red.*—Make a decoction of two pounds peachwood and one pound fustic, work the goods in this for fifteen minutes; lift up, and add four ounces, by measure, red spirits; work again fifteen minutes; wash in cold water, and finish.

A variety of tints may be dyed in this way by altering the proportions; and by adding a little logwood, clarets and such shades can be produced; but these common colors do not stand the air well.

15. *Cochineal Pink.*—This hue is dyed in the same manner as the crimson, only using much less cochineal; about half a pound will make a good color. Different shades of pink, rose, and crimson can be dyed by this method, by varying the quantities of stuff used.

16. *Cochineal Scarlet.*—Dye a deep orange by annotta—see *Orange*, page 660; and proceed in the same way as for crimson, passing through the spirits, and then cochineal, as stated above.

Different shades of common reds and crimsons may be dyed by mixing up the following:—Make a strong decoction of lima or brazil-wood by boiling, using at the rate of one pound wood to the gallon of water. When the boiling has ceased and the wood settled to the bottom, decant the clear and allow it to cool for twenty-four hours, then decant again from any sediment that may have collected, and to every gallon of liquor add half a pint plumb spirits, stir well, and let stand for several hours, when it is fit for use.

17. *Common Crimson.*—Into a copper or stoneware vessel put some of the above liquor, work the goods in it for half an hour; then wash out in cold water until no taste of spirits is perceptible in the cloth; wring, and dry.

18. *Common Scarlet.*—Dye the goods an orange by annotta—see *Orange*, page 660; and then work in the peachwood preparation in the same way as dyeing common crimson; wash out, and dry.

19. *Rubys, Maroons, et cetera.*—Take one pound of cudbear and boil for fifteen minutes in a bag; work the silk in this solution for half an hour. If the shade required be of a bluish tint, lift, and add three ounces, by measure, liquid ammonia; work ten minutes, and wring and dry.

If the shade required be of a red hue, lift, and add two ounces, measure, red spirits; work ten minutes; wash out, and dry.

If a brown hue is wanted, use along with the cudbear a decoction of four ounces fustic; work in this, and raise with two ounces red spirits, as above.

If a deep violet hue is desired, employ along with the cudbear a decoction of four ounces logwood; work in it, and raise with two ounces red spirits, as above.

20. *Sky-Blue.*—To one pint of sulphate of indigo add two or three gallons boiling water; then put into this a piece of woollen cloth, such as an old blanket; after steeping for a day, take it out and wash in cold water.

If the sky-blue required be very light, make up a vessel with warm water, about 98°, steep the blue cloth in this for a few minutes, and wring out, when as much blue will be dissolved off as will dye the silk; add an ounce of alum in solution, and work the silk in this for twenty minutes; wring out, and dry.

If the blue required be deep, then, to the warm water in which the blanket is put, add one ounce of pearl-ash, and proceed as detailed; but before adding the silk, a few drops of sulphuric acid may be poured in with the alum to neutralize the alkali.

If indigo extract be used, then the blanket or woollen cloth is not required, but to the requisite quantity of water add half an ounce of extract, with one ounce of alum in solution, and work the silk as stated; less or more of the extract is used according to the depth of shade required.

For prussian blues on silk, see page 648.

21. *Lavender.*—Into as much water as will work the goods in easily, put one pint of spirit plumb liquor; stir well, and work the goods in this for twenty minutes, then wash out in cold water, and dry.

Darker or lighter shades can be dyed by using less or more of the plumb liquor.

If a blue tint of lavender is required, add to the plumb liquor solution, before putting in the goods, two or three drops of sulphate of indigo, or extract, and proceed as stated.

22. *Lavender—Another method.*—Into a vessel with warm water as hot as the hand can bear, dissolve a little white soap, enough to raise a lather; then add one gill archil liquor, and work the goods in this for fifteen minutes; wring out, and dry.

Boil one ounce of cudbear, and add the solution to the soap and water, instead of archil, which will give a lavender having a redder tint than that with the archil. If a still redder shade of lavender be required, the soap may be dispensed with.

23. *Wine Color*, *Violet*, *Lilac*, *et cetera.*—Into a copper pan or stoneware vessel, put as much of the plumb liquor as will work the goods in; then work in this for twenty minutes; wash out in two or three waters, or until the goods have no taste of the plumb, then dry.

If a rich blue tint is required, add to the plumb one ounce, by measure, sulphate of indigo, or extract. If a red tint is desired, dye the cloth first a lavender by cudbear, without soap; then work through the plumb liquor, without indigo.

The plumb liquor used for this color is not thrown away; it is either put back into the stock tub, or into another vessel kept for that purpose, when it may be used over again. If indigo has been taken, it must not be put back into the stock plumb, or it will give the whole a blue shade—all such mixture should be kept separate.

24. *French and Pearl White.*—Into hot water dissolve a quantity of white soap, as much as makes a lather, and then add about half an ounce, by measure, archil; work the goods in this for ten minutes, and finish out the soap.

A little cudbear may be used instead of archil, less or more according to the shade required.

25. *Another method.*—Into a vessel of cold water, add about one ounce, by measure, of plumb liquor; work the goods for ten minutes; wash out, and dry.

For these shades the goods should be perfectly white previous to dyeing.

26. *Weld, Yellow.*—Work the silk for an hour in a solution of alum, about one pound to the gallon, wring out, and wash in a vessel with warm water. Boil two pounds weld, strain the liquor, and work the alumed silk in this for half an hour, then add one pint of the alum solution to the weld bath, and return the silk; work for ten minutes longer, and wring out and dry.

This gives a rich lemon-yellow; by adding more weld, deeper shades are produced; or by using a little annotta, amber and straw tints are obtained.

For other shades of yellow on silk, see page 624.

27. *Gold and Straw.*—Into warm water with white soap, add two pints annotta liquor; work in this fifteen minutes; wash out, and then work twenty minutes through a decoction of eight ounces bark; lift, and add one ounce, by measure, red spirits; work other ten minutes, wash out, and finish.

Different tints of these colors may be dyed by varying the quantity of annotta bottom and bark.

28. *Salmon, Flesh, Nankeen, Buff, et cetera.*—Make a solution of white soap in warm water, and to this add one pint of annotta liquor; work twenty minutes, wring out, and finish. If the shade is not deep enough, add a little more annotta.

If a red tint is required, such as salmon or flesh color, the goods are washed out of the soap, and finished in cold water, in which two ounces of alum are dissolved.

29. *Orange.*—The silk is wrought for fifteen minutes in a strong solution of annotta—page 656—made warm; then wash in warm water, and dry.

The annotta made up for silk should be with soft soap, instead of potassa or soda, or only a very little of these alkalies should be added.

30. *Yellow Drab.*—Into a vessel with warm water add one pint annotta liquor; work in this for fifteen minutes, and wash; then work another quarter of an hour into a decoction of half a pound sumach and one pound fustic; lift up, and add four ounces copperas in solution and one ounce alum; work ten minutes, and wash in cold water, and dry.

A diversity of shades of drab may be dyed in this way, by varying the proportions of the stuff, and adding with the fustic small quantities of log and peachwood.

31. *Drab.*—Work the goods for fifteen minutes in a decoction of eight ounces sumach, and the same of fustic; lift, and add four ounces copperas; work twenty minutes, and wash out in cold water. In another vessel with warm water add half a pint archil liquor; work fifteen minutes in this, and dry out.

If a greenish tint be required, add a decoction of four ounces fustic to the archil, and half an ounce, by measure, of chemic—page 624. If a purple tint is sought, add, instead of the chemic, one ounce of alum in solution.

A great variety of tints may be produced by a slight alteration in some of these ingredients.

32. *Slate or Stone Color.*—Into a decoction of one pound sumach, four ounces fustic, and four ounces logwood, work the silk for half an hour; lift, and add a solution of four ounces copperas; work other thirty minutes, wash in cold water, and finish.

A variety of tints can be produced by this method, by taking different proportions of the stuffs.

33. *Common Green.*—Steep for an hour in an alum solution of one pound to the gallon; wash in warm water, and work for thirty minutes in a decoction of six pounds fustic; then add two ounces, by measure, indigo extract; work other thirty minutes; wash, and finish.

Should the shade be too yellow, as the extract often varies in quality, add more extract to the fustic before finishing.

Deeper and lighter shades are dyed by this method, by using more or less of each stuff.

34. *Another method.*—Work for forty minutes in a decoction of four pounds fustic; lift, and add one pound alum in solution, and two ounces, by measure, of indigo extract; work for half an hour in this; wash out in cold water, having in it half a pint of alum solution, and finish.

35. *Pea Green.*—Steep the silk for an hour in an alum solution of eight ounces to the gallon of water, and then wash out in warm water; boil four pounds ebony wood chips for an hour; take the clear, and work the silk in it for thirty minutes; lift, and add half an ounce indigo extract; work ten minutes; wash in cold water, having half a pint of alum solution in it. and dry.

Care has to be taken in adding the extract, lest the quantity given be too much for the shade required; it may be better to add less, and if found not enough, lift, and add more.

36. *Bottle Green.*—Dissolve two pounds alum and one pound copperas; work the silk in this for an hour, and wash out in warm water; then work for half an hour in a decoction of six pounds fustic; lift, and add two ounces, by measure, indigo extract; work twenty minutes, wash out, and finish.

37. *Another method.*—Proceed exactly as described for common green; but add one pound of logwood to the six pounds of fustic, and operate in every way the same.

If a deeper shade be required, a little more logwood may be added.

38. *Olive.*—Work the silk for half an hour in a solution of one pound of copperas and four ounces of alum; wash out in hot water, and then work half an hour in a decoction of two pounds fustic and four ounces of logwood; lift, and add half a pint alum solution or two ounces dissolved; work ten minutes in this; wash, and dry.

If the shade looked for have more of a green hue than pattern, add a little chemic to the last water, and work ten minutes, and dry out.

39. *Light Olive.*—Dye a light prussian blue—see *Sky-blue*—then work for twenty minutes in a decoction of two pounds fustic and half a pint archil liquor; lift, and raise with half a pint alum solution, or one ounce dissolved; work ten minutes, and finish.

PREPARATION AND DYEING OF WOOLLEN STUFFS.—Woollen is also banded with twine into spindles, previous to being put under operations for scouring or dyeing. It is then steeped overnight in soap lie, or old alkaline solutions, and then scoured through clean soap to remove all oil or grease that may be upon the wool; or, what is more common, a scouring liquor is prepared with one pound of soft soap and one pound of common soda, or half a pound of soda ash, in ten gallons water, and scoured through this.

This is the only preparation that new wool is subjected to previous to dyeing.

For re-dyes every care should be taken to remove all grease or oil first, or no good dye can follow. This is done by steeping and scouring in soap and soda. If the remaining color be unequal or dark, the goods are steeped or wrought for a little in a sour made up of bisulphate of potassa—dissolving two ounces to the gallon of water.

Woollen is always dyed hot; the liquid usually being near to the boiling point, which necessitates its being dyed in a boiler. Iron vessels are not used for this purpose. Copper, and copper with tin, is most generally used. The dyestuffs, such as ground wood, are generally put into the boiler and the goods wrought with it, but it is cleaner to make a decoction and use the clear liquor.

All washings are made in cold water, except warm be specified in the directions.

In the following receipts, the quantity of goods referred to is ten pounds, whether in cloth or yarn:—

1. *Black.*—Work for twenty minutes in a bath with eight ounces camwood; lift, and add eight ounces copperas; work other twenty minutes; then withdraw the fire from the boiler, and submerge the goods in the liquor overnight; then wash out. Into another bath, with five pounds logwood and one pint chamber lie, work for an hour; lift, and add four ounces copperas; work in this half an hour longer; wash, and dry.

2. *Brown.*—Work for an hour in a bath made up with two pounds of fustic, two pounds of madder, one pound of peachwood, four ounces of logwood; then lift, and add to the bath a solution of two ounces of copperas, and work half an hour in this; wash out, and dry.

3. *Brown.*—Work for an hour in a bath of four pounds of fustic, two pounds of camwood, half a pound of logwood; lift, and add to the bath four ounces of copperas; work half an hour in this; wash, and dry.

For other methods of dyeing black and brown, see page 645.

4. *Crimson.*—Work in a bath for one hour with one pound cochineal paste, six ounces dry cochineal, one pound of tartar, one pint of protochloride of tin; wash out this, and dry.

5. *Scarlet.*—Work for an hour in a bath with one pound of tartar, two ounces of dry cochineal, eight ounces of sumach, eight ounces of fustic; wash out, and dry.

6. *Red.*—Work half an hour in a bath with one ounce of bichromate of potassa, one ounce of alum; wash out this through cold water; then work for half an hour in another bath with three pounds of peach or limawood; lift, and add one ounce of alum; work in this for twenty minutes; wash, and dry.

7. *Claret Red.*—Work for an hour in five ounces of camwood; lift out, and expose until the goods are well drained and cold; in the interim, add to the bath with

the camwood, four ounces of copperas, two ounces of alum, eight ounces of logwood; work the goods in this for half an hour; wash, and dry.

8. *Lac Scarlet.*—Work for half an hour in a bath with one pound of tartar, eight ounces of sumach, two pounds of lac; lift, and add about a gill of bichloride of tin, and work in this for half an hour; lift, wash, and dry.

9. *Pink.*—Work one hour in a bath with one pound of tartar, eight ounces of alum, one pound of cochineal paste, one gill measure of red spirits; wash out in cold water, and dry.

10. *Yellow.*—Work for twenty minutes in a bath with eight ounces of tartar, eight ounces of alum; lift, and add to the bath two pounds of bark, eight ounces of sumach, eight ounces of fustic, one pint of red spirits; work in this for forty minutes; wash out, and dry.

11. *Orange.*—Work for forty minutes in a bath with two pounds of sumach, three ounces of cochineal dry, one pound of fustic, eight ounces of tartar, one pint of red spirits; wash out this, and dry.

12. *Sky-Blue.*—Work in a bath for half an hour with eight ounces of argol, one pound of alum, one gill of indigo extract; wash out this, and dry.

Different depths of shade may be made by varying the quantities of indigo extract.

For other shades of blue, see page 648.

13. *Pigeon Blue.*—Work in a bath for forty minutes with two ounces of chrome, four ounces of alum, one ounce of tartar; wash from this in cold water, and then work for half an hour in another bath with three pounds of logwood; lift, and add one ounce of verdigris; work for fifteen minutes, and wash, and dry.

14. *Apple Green.*—Work for half an hour in a bath with one ounce of chrome, one ounce of alum; wash through cold water, and then work for half an hour in a second bath with two pounds of fustic and eight ounces of logwood; wash, and dry.

A variety of this shade can be obtained by diversifying the proportions and quantities.

15. *Green.*—Work for fifteen minutes in a bath with five pounds of fustic, two ounces of argol, five ounces of alum; lift, and add half a gill of indigo extract; and then work for half an hour, and dry.

If the green seem too yellow, a little more extract of indigo may be mixed with the others.

16. *Fast Green.*—This is first dyed blue in the indigo or woad vat, according to the depth of green required, and then work for an hour in a bath with four pounds of fustic, two pounds of alum, and dry out.

By dyeing the vat blue lighter than is required for the green, and adding to the bath with the fustic a little logwood, will give the required depth and a good shade; but the color is not so fast.

See page 648 for other shades of green.

17. *Olive.*—Work for an hour in a bath with ten ounces of fustic, eight ounces of logwood, four ounces of madder, two ounces of peachwood; lift, and add to the same bath four ounces of copperas in solution, and work for half an hour, and dry—see page 648.

18. *Wine Color.*—Work the goods for an hour in a bath, with four pounds of cudbear, and dry.

If a darker shade be required, give more cudbear; if the tint be desired bluer, add, after half an hour's working, one gill of ammonia: if a redder tint is wanted, add a wine-glassful of hydrochloric acid.

If the acid be added, the goods should be washed before drying.

19. *Light Violet.*—Work for an hour in a bath, with four ounces of cudbear, four of logwood, two of barwood or camwood, two of peachwood; lift, and add two ounces of alum in solution, and work half an hour, and dry.

20. *Puce.*—Work in a bath for one hour, with ten ounces of logwood, one ounce of camwood, eight pounds of cudbear; lift, and add two ounces of copperas in solution; work half an hour, and dry.

21. *Brown Drab.*—To the dye bath, add two ounces ground madder, one ounce peachwood, two ounces of logwood, six of fustic, and work in this for thirty minutes; lift up, and add three ounces of copperas in solution; mix well, and work the goods in this for other thirty minutes; wash, and dry.

This shade can be greatly varied, either by altering the quantity of stuffs, or the proportions of any of them; if a redder tint be required, add more peachwood or madder—the latter gives the drab hue; if more yellow, add fustic; if more slate or black, add logwood, and *vice versâ.*

22. *Stone Drab.*—Into the proper proportion of water add one ounce of peach or limawood, two ounces of logwood, half an ounce of fustic; work in this for twenty minutes, and then lift out, and add to the dye bath one ounce of sulphate of iron in solution; stir well, and work in this for another half hour; lift out, and expose to the air for a short time; wash, and dry.

A diversity of shades may be dyed, by altering the quantities and the proportions of the dyestuffs.

23. *Slate.*—Work for half an hour in a bath, with eight ounces of logwood, one ounce of fustic; lift, and add to the bath a solution of one ounce of alum, half an ounce of copperas; work in this half an hour; wash, and dry.

Different tints of this color can be obtained by varying the stuff; if more blue be required, use less alum and more copperas; if more to the purple, less fustic and more alum; and so by a very little practice any particular hue can be dyed.

For dyeing woollen blue in vats—see article VATS—which serve both for woollen and silk; the operation is simply dipping or working in the vat, and then exposing to the air.

MIXED FABRICS DYED TWO COLORS.—Mixed fabrics of cotton and woollen, as coburgs and damasks, are very common; these are either dyed all of one hue, or the cotton and woollen are dyed of different colors. This last is seldom done, except with new goods, or in cases where very light-colored goods are wanted a dark shade, in which case a light and dark tint may be communicated. The process for doing this is very simple. As the process used for woollen will seldom produce the same color on cotton, the two have to be dyed separately. For most colors it is necessary to dye the woollen first, and then the cotton; in a few the cotton is dyed first. In most cases, the processes given will serve the purpose; as, for instance, *Green and Pink.*—The woollen is first dyed a green, by any of the processes—No. 15 or 16, page 666—and then the cotton is dyed pink, by the process, page 625.

Green and Crimson.—Dye the woollen by working for an hour in two pounds of tartar, four pounds of alum, six pounds of fustic, and then add half a pint of indigo extract, wash out, and lay overnight in six pounds of sumach; work half an hour in red spirits, made to 2° Twaddle; wash and work for an hour in five pounds of peachwood at hand heat; raise with alum; wash, and finish.

Blue and Orange.—First dye the cotton a blue by the blue vat, wash, and then dye the woollen by working one hour in two pounds of tartar, eight ounces of cochineal, two pounds of fustic, and two pints of bichloride of tin; wash from this, and dry.

In this way almost any two colors may be dyed upon cotton and woollen, although woven together, by proceeding as the receipt for the tint required on each sort of fibre; and except as in last recipe, where cotton is dyed by the blue vat, and consequently fast, the woollen is always to be dyed first. The same rule is applicable to silk and woollen. The two have to be dyed separately, although in many cases the silk becomes more imbued during the dyeing of the woollen than the cotton is.

A mixture of silk and cotton, when required of two shades, has also to be done in the same manner; but it is much more difficult, and cannot be done with all kinds of colors; it is a process, however, seldom resorted to. But the intelligent dyer will be able to dye any two tints by following the rules and receipts given.

MIXED FABRICS DYED ONE COLOR.—Should the mixed fabrics be required all of one color, the same double process has often to be adopted, especially when the fabrics are cotton and woollen; as, for instance,

Black on Cotton and Woollen.—The woollen is dyed first, as in page 665; and then, to dye the cotton, the goods are laid in sumach, and dyed as in page 659, and so on for any color of these mixed fabrics.

Brown on Cotton and Woollen by one Process.—Work the goods for two hours in catechu, same as page 656; then work for an hour at boiling heat with eight ounces of chrome and two ounces of tartar; lift out, and work an hour in two pounds of fustic and eight ounces of cudbear; wash, and dry. Should a deeper shade be required, or a tint more of the chocolate hue, add with the cudbear four ounces of logwood.

Black on Silk and Woollen by one Process.—Work an hour in a solution of eight ounces of tartar and eight ounces of copperas, and wash out; work for fifteen minutes in a decoction of four pounds of logwood; lift, and add one ounce bichromate of potassa; work half an hour, and dry.

Black on Cotton, Silk, and Woollen, by one Process.—Steep for six hours in two pounds of sumach, then work for an hour in a solution of six ounces of tartar, six ounces of sulphate of copper, and six ounces of copperas; wash from this, and work half an hour in a decoction of four pounds of logwood; lift, and raise with one ounce of copperas; work ten minutes; wash, and dry. Should a very deep black be required, add one pound of bark with the logwood; all else the same.

Drabs on Cotton, Silk, and Woollen, by one Process.—Work half an hour in eight ounces of sulphate of iron, and four ounces of tartar; lift, and drain; then work for half an hour in four ounces of logwood and one ounce of bichromate of potassa; wash out, and dry.

By varying the quantity of these stuffs, or by using a little fustic or peachwood in the last bath, a great variety of shades of drab, slates, or fawns may be produced, the different fibres being equally dyed.

These few receipts for dyeing mixed fabrics will show the care required in such operations; nevertheless, by a little practice they all become simple, and new methods and modifications are continually being introduced.

An interesting and ingenious application of sulphate of indigo, prepared in a certain form, has been proposed for dyeing particular shades of blue or lilac on woollen and silk, by M. E. HAEFFELY; the paper is nearly given as read to the Manchester Philosophical Society:—

This chemist commences his essay with drawing the attention of the society to a new fact, demonstrated in the successful application on worsted and silk of the red sulphate of indigo.

This chemical compound is produced by the action of sulphuric acid upon indigo, and by throwing the mixture thus obtained into a large quantity of water a few minutes after the contact. By this means a red-colored precipitate is formed, which, when well and thoroughly washed on a filter, represents the red compound in question, a very different production from the blue sulphate of indigo in its composition, properties, and as regards the shades produced by it.

He has been able to produce with this red sulphate of indigo, shades superior in all respects to those obtained by the employment of the indigo extract, imitating the prussian blue, and likewise purple shades bearing an imitation of those produced by the use of logwood and cudbear, which tints, he observes, cannot be produced from the commercial indigo carmin. Owing to this he was induced to communicate the results of the experiments he made in this matter, and at the same time exhibit for inspection some patterns, the effects of the putting into operation of both processes, so that the difference between the two may be fairly estimated. After a careful examination of these patterns, he felt assured every one would be inclined to give a preference to the blue and purple colors obtained by the use of the red sulphate introduced into commerce, and applied by dyers with success in some of the Yorkshire establishments.

He next entered into a few details respecting the chemical nature of these two sulphates. Upon an examination of the formulæ of the two chemical bodies referred to, it will be found that the ordinary indigo extract is, properly speaking, a hyposulphate of dehydrogenised indigo

$$= N\ C_{16}\ H_4\ O_2\ S_2\ O_5,$$

the formula of the indigotin being

$$N\ C_{16}\ H_5\ O_2,$$

whilst the red compound is a sulphate of indigotin—

$$N\ C_{16}\ H_5\ O_2,\ H\ O,\ S\ O_3.$$

Upon a comparison of these two formulæ, it will be remarked that, in the case of the indigo extract, the indigo and the sulphuric acid have undergone remarkable alterations: the indigo having lost a portion of its hydrogen, and the sulphuric acid a portion of its oxygen, —and these two elements, hydrogen and oxygen, having united to form water. But in the case of the red sulphate, the indigo and the sulphuric acid have entered into combination *without* undergoing any change.

As in the composition of the red sulphate, the tinctorial matter is, or appears, *unaltered*, he was induced to entertain the supposition that it might be beneficially used in dyeing for obtaining solid blues directly, an operation which might probably replace with advantage the process of obtaining blues from vats.

A circumstance which is in favor of the possibility of fixing this coloring matter on fabrics in a state of indigotin is, that some organic substances—such as sulphovinic acid, sulphoglyceric acid, and other sulphoacids —possess the property of being decomposed, and resolving themselves into their primitive constituents by a simple ebullition in water.

This red sulphate of indigo may be ranked in that type of organic bodies, where it figures under the name of *sulphopurpuric acid.* As it ought to partake of the properties of the series of compounds mentioned, it should necessarily, on its ebullition in water, decompose itself into *free indigo* on one side, and into *free* sulphuric acid on the other. Consequently, HAEFFELY presumed, that by immersing fabrics in the vessel where the process was going on, and at the moment of the separation of the coloring matter, he could fix this color upon the fabrics so introduced.

But the first experiment made did not turn out to be satisfactory. Cotton remained untouched by the color, whilst the worsted took off and successfully retained the tinctorial matter. Three consecutive trials were made on the occasion: the first in a neutral bath, the second in an acid bath, and the third in an alkaline one; but in all the three cases, so far as the cotton was concerned, there was no gratifying result. Hence it appears that the cotton has no affinity for this indigo. But silk and worsted may be effectually dyed in the way indicated, if the bath be only kept acid.

As already observed, some of these patterns imitate the prussian blue, and those washed in soap or alkaline water resemble the purple produced from logwood and cudbear, which shades could not, up to the present time, be produced by the employment of indigo alone.

A question which it will now be worth while particularly to inquire into is this—whether the indigo appears *on these fabrics* as indigotin, or as sulphopurpuric acid, or as a modification of this acid?

The opinion inclined to is, that it is a modification of indigotin, or of the acid coloring substance; for he found that this sulphopurpuric acid, in contrariety to the view generally entertained, is an intense red-colored compound *when dry*, and not a deep blue one.

Nevertheless, upon examining the patterns dyed with this *red compound*, it will be found that they *are blue on these fabrics*, and *not red;* and those patterns passed through alkali *are purple*, an effect which is not produced by indigotin.

This question has not been yet completely solved, and for the present this chemist only takes the liberty of calling attention to the new shades obtained by the employment, in the dyeing process, of this sulphopurpuric acid, namely, the blue, imitating prussian blue, and the indigo purple imitating the shades obtained by the use of logwood.—*Haeffely.*

TURKEY-RED.—The principal use of madder is to dye cotton cloth different shades of red; and by far the finest hue of all is that which is known in this country and on the continent by the name of Turkey or Adrianople red—one of the most durable colors known. Everything seems to prove that the method of dyeing this tint —the characteristic of which consists in previously impregnating the goods with an oily or fatty substance— was first discovered in India, where, as travellers affirm, the natives have been wont, from time immemorial, to steep the yarns which they intend to dye in liquids containing fatty matter—such as milk, for example. It was not, however, till after it had made its way into other parts of Asia, and become known in the countries of the Levant, undergoing at the same time important modifications, that this art was first introduced into France towards the middle of the last century. In 1747, MM. FERQUET, GOUDARD, and D'HARISTOY brought a party of Greek dyers into that country, and formed two establishments—one at Darnetal, near Rouen, and the other at Aubenas, in Languedoc. Nine months later, a person named FLACHAT, who had long resided in the Ottoman empire, brought over workmen, with whom he formed at St. Chamont, near Lyons, a third establishment for the dyeing of Adrianople-red—so called from the high celebrity then enjoyed by the productions of that city. But these foreigners could not long keep their art secret; they had soon numerous imitators; and, in 1765, the French government, convinced of the value and importance of this method of dyeing, made the processes known to the public. Many establishments were formed in various parts of the country; but it appears that the only successful ones for some years were those at Rouen. From these parts, the Turkey-red dye gradually made its way into Alsace, Switzerland, Great Britain, and different parts of Germany. At first, the cotton was only dyed in the yarn; and it was not till 1810 that the cloth itself was dyed directly of this color at the establishment of Messrs. KŒCHLIN, Mulhausen, and that of L. WEBER.

It is stated by the late Dr. THOMSON of Glasgow, and other authorities, that the first Turkey-red work in Great Britain was established in that city about seventy years ago by M. PAPILLON. It appears, however, from a paper on the Art of Dyeing, read before the Literary and Philosophical Society of Manchester, by Mr. THOS. HENRY, in 1786, and quoted by Mr. BAINES in his History of the Cotton Manufacture, that M. BORELLE, another Frenchman, introduced the art of dyeing Turkey-red at Manchester, probably some years previous to its introduction at Glasgow, and that he obtained a grant from Government for the disclosure of his plans, as M. PAPILLON afterwards did from the commissioners and trustees for manufactures in Scotland; but the method of the latter obtained the most decided success. It was in the year 1783, that Mr. DAVID DALE and Mr.

GEORGE MACINTOSH—father of the late Mr. CHARLES MACINTOSH, the inventor of the well-known waterproof fabrics—engaged PAPILLON, who was a dyer at Rouen, to settle in Glasgow, and he there founded and carried on for many years, in partnership with Mr. MACINTOSH, the celebrated Turkey-red business now conducted by the firm of Messrs. MONTEITH and Co. The period having expired in 1803, when the process was to be divulged, the commissioners and trustees above mentioned laid a complete account of it before the public. Since that period, Turkey-red dyeing has been conducted in Glasgow, and also in Lancashire, on a very extensive scale.

The following is the process given by Dr. THOMSON, as followed by the most skilful Turkey-red dyers in Glasgow:—

1. The cloth is steeped in a weak alkaline lie to remove the weaver's dressing. This is technically called the *rot steep.* From four to five pounds of caustic potassa are generally employed for every one hundred pounds of cloth. The temperature of the solution is from 100° to 120°. The cloth is kept in the steep for twenty-four hours, and then well washed.

2. From seven to ten pounds of carbonate of soda are dissolved in a sufficient quantity of water to keep the cloth—always supposed to be one hundred pounds—wet. In this solution the cloth is boiled for some time.

3. It is upon the third process that the beauty of the color depends more than on any other. Without it the dye cannot be produced on new cloth. But when old cotton cloth that has been frequently washed—a cotton shirt, for example—is to be dyed, this process may be omitted altogether.

A liquor is composed of the following ingredients:—

One gallon Gallipoli oil;

One gallon and a half of soft sheep's dung;

Four gallons of a solution of carbonate of soda, of the specific gravity 1·06;

One gallon of solution of pearl ashes, of the specific gravity 1·04.

These to be mixed up with a sufficient quantity of cold water, to make the whole mixture amount to twenty-two gallons. The specific gravity of this liquor should be from 1·020 to 1·025.

This menstruum has a milk-white appearance, and is in fact a kind of imperfect soap. It is put into a large wooden, open, cylindrical vessel, called the *liquor tub*, and is kept constantly in motion, to prevent subsidence, by wooden levers driven round in it by machinery. This liquor is conveyed by tin pipes to a kind of trough, in what is called the *padding machine*, where the cloth is thoroughly soaked in it. The longer the cloth is allowed to remain impregnated with this solution, the better does it take the dye. Fourteen days is the least period that this impregnation is allowed to remain.

The padding machine is similar in principle to that employed for starching, as described at page 317, and other forms of it will be described and delineated in connection with the *padding style* of calico-printing.

The sheep dung gives the cloth a green color, and is found materially to assist the bleaching process, to which it is afterwards subjected. It is found to increase the rapidity of the bleaching, especially when the cloth is exposed on the grass between the different operations

4. In favorable weather, the cloth impregnated with the imperfect soap of No. 3, is spread upon the grass to dry. But in rainy weather it is dried in the stove or *hot flue.* This method of exsiccating dyed and printed goods will likewise be fully described in connection with calico-printing.

5. The cloth thus exsiccated is a second time impregnated with the oleaginous liquid of No. 3. It is then dried again.

The impregnation and drying are repeated a third time.

6. The cloth is steeped in a weak solution of pearl ash, of a specific gravity from 1·0075 to 1·01, heated to the temperature of 120°. From this liquor it is wrung out, and again dried.

7. A mixture is made of the following substances:—

One gallon Gallipoli oil,

Three gallons soda lie, of specific gravity 1·04,

diluted with as much water as will make up the whole to twenty-two gallons. In this liquid the cloth is soaked as it was in that of No. 3.

The cloth thus impregnated is in fine weather dried on the grass, in rainy weather in the stove.

8. The process No. 7 is repeated thrice, and after each soaking the cloth is exposed for some hours on the grass, and finally dried in the stove.

9. The cloth is steeped in a mixed lie of pearl ash and soda, of the specific gravity 1·01 to 1·0125, heated to the temperature of 120°. It is allowed to drain for some hours, and then well washed; it is then dried in the stove. The object of this process is to remove any superfluous oil which might adhere to the cloth. Should any such oil be present, the succeeding process, the *galling*, could not be accomplished.

10. For the galling, eighteen pounds of Aleppo galls are to be boiled for four or five hours in twenty-five gallons of water, till the bulk is reduced to about twenty gallons. This liquid, after straining, is strong enough to impregnate one hundred pounds of cloth with the requisite quantity of nutgalls. Of late years, sumach from Sicily has been substituted for nutgalls; thirty-three pounds of the former being reckoned equivalent to eighteen pounds of the latter. Sometimes a mixture of nine pounds of nutgalls and sixteen pounds and a half of sumach is employed.

In this liquor, heated to 80° or 100°, the cloth is fully soaked. The sumach gives the cloth a yellow color, which serves to improve the madder-red, by rendering it more lively.

11. The next step is to fix the alumina on the cloth. This process is essential, because without it the madder dye would not remain, but would be washed off by water.

In this country alum is used by the manufacturers, but in many parts of the continent acetate of alumina is employed. To form the alum liquor of the Turkey-red dyers, to a solution of alum, of the specific gravity 1·04, as much pearl ash, soda, or chalk is added, as is sufficient to precipitate the alumina contained in the alum. Through this muddy liquor, which should have a temperature of from 100° to 120°, the cloth is passed.

and steeped for twelve hours. The alumina is imbibed by the cloth, and combines with its fibres.

12. The cloth thus united with alumina is stove-dried, and then washed out of the alum liquor.

13. These essential preliminary steps having been taken, the cloth is ready to receive the red dye.

From one to three pounds of madder, reduced to the state of powder, are employed for every pound of cloth; the quantity depending upon the shade of color wanted. The cloth is entered into the boiler while the water is cold. It is made to boil in an hour, and the boiling continues for two hours. During the whole of this time the cloth is passed through the dyeing liquor by means of the winch.

For every twenty-five pounds of cloth dyed, one gallon of bullock's blood is added. This is the quantity of cloth dyed at once in a boiler. The addition of the blood is indispensable for obtaining a fine red color. Many attempts have been made unsuccessfully to leave it out. It seems probable that the coloring matter of blood is fixed on the cloth. Its scarlet tint would doubtless improve the color of madder-red.

14. *Madder-brown*, by this process, is fixed on the cloth as well as madder-purple or madder-red. This gives the cloth a brownish-red and rather disagreeable color. But the brown tinge not being nearly so fixed as the red, it is got rid of altogether by the next process, which is known by the name of the *clearing* process. The cloth is boiled for twelve or fourteen hours in a mixture of five pounds soda, eight pounds soap, and from sixteen to eighteen gallons of the residual liquid of No. 9, with a sufficient quantity of water. By this seething, the brown coloring matter is mostly removed, and the cloth begins to assume the fine tint which characterizes Turkey-red dyed cloth. It is still further improved by the next process.

15. Five or six pounds of soap, and from sixteen to eighteen ounces of protochloride of tin in crystals, are dissolved in water in a globular boiler, into which the cloth is put. The boiler is then covered with a lid which fits close, and the ebullition is conducted under the pressure of two atmospheres, or at a temperature of 250·5°. The boiler is furnished with a safety valve and a small conical pipe, the extremity of which has an opening of about three-tenths of an inch in diameter, from which there issues a constant stream of steam during the operation. The salt of tin is found materially to improve the color. Probably the oxide of tin combines with the oleaginous acid of the soap, fixed in the cloth. This insoluble soap doubtless unites with the red coloring matter of the madder, and alters the shade.

16. After all these processes, the cloth is spread out on the grass, and exposed to the sun for a few days, which finishes the clearing.

Such is a sketch of the Turkey-red dyeing, as practised in the principal works in Glasgow. Many attempts have been made to shorten these tedious processes, but hitherto without success. The impregnation with oil, or rather soap, is essential. If one, two, or three immersions be omitted, the red is inferior in proportion to these omissions. Doubtless this soap combines with, and remains attached to the cloth. And the same remark applies to common soap.

Cloth bleached by means of bleaching powder does not produce a good red. Doubtless the fibres of the cotton wool combine with lime, or rather with sulphate of lime, which, by decomposing the oleaginous soap, prevents it from combining with the cloth. But cloth bleached by the old process—namely, boiling in lie or soap, and exposure to the action of the sun, answers perfectly. The colors would be as good without the galls as with them. But there would be considerable difficulty in sufficiently impregnating the cloth with the alum liquor, without its being previously passed through the gall decoction, especially if the cloth be in the least degree greasy.

French Process.—The following process is given on the authority of M. PERSOZ, as generally practised in France at the present day:—

1. *Oiling the Goods.*—Assuming that the goods to be dyed are 1000 kilogrammes—2200 pounds—of cotton, and that they have been previously well washed and scoured in a soap bath, a liquor composed of the following ingredients is employed:—1287 to 1430 pounds of fat oil, 3300 pounds or 330 gallons of water, holding in solution 20 to 22 pounds of carbonate of potassa.

The oil, the water, and the carbonate of potassa, in these proportions, are divided into three equal parts, with which three parts of white liquor are formed successively as required, incorporating with the oil in small portions at a time the quantity of alkaline solution necessary to produce an emulsion. One-third of the goods to be oiled is padded in the first portion of this white liquor, and after this operation the pieces are laid together in a heap in a fresh and cool place, where they are left for ten to twelve hours; they are then put to dry in an atmosphere heated to 140° Fahr.

While this desiccation of the first portion of goods is in progress, operations are commenced on the second, which are passed into the second portion of white liquor; and when these are soaked, macerated, and put to dry, the same operations are performed with the third portion of goods in the remaining portion of white liquor. By this means the process is carried on without intermission; for, while the pieces last padded are lying at rest, others are in the drying-room, and others are being steeped in the liquor.

After each padding in the white bath, followed by the lying of the goods in a heap, and the subsequent drying process, the different portions of goods are returned to their respective white liquors, in which they are again worked. When the bath begins to fail, either a little tepid water is added, or a certain quantity of *old white liquor* proceeding from the washings; and this operation is repeated several times, according to the quantity of oil which it is desired to fix on the stuff.

The number of paddings in the white bath, which are always performed in the same manner—that is to say, followed by a period of rest, and then desiccation in a heated atmosphere—is generally seven or eight; the next process is what is termed the *degraissage*, or the removal of the superfluous oil, which is performed by macerating the goods twice, successively, for twenty-four hours each time, in a solution of carbonate of potassa at 1·2° Twaddle. The liquid which is wrung or pressed out of them constitutes the *old white liquor*, which is employed again in the oiling operations. The goods being carefully rinsed, are now ready to receive the galling.

Galling or Mordanting.—This operation is performed on two occasions: first, before the first maddering, and again before the last maddering.

Twenty-two pounds of bruised gall-nuts are subjected to several boilings till well drawn; and sufficient water is added to the product, to form in the whole about sixty-six gallons, in which thirty-five pounds of alum are dissolved with the assistance of heat. This liquor is introduced hot into the padding machine, and kept at the temperature of about 160° Fahr. during the whole time that the goods are worked in the bath. This quantity of gallo-aluminous liquid is about sufficient to mordant one-half of the goods under treatment—that is to say, 500 kilogrammes, or 1100 pounds, of cotton. On taking the goods from the padding machine, they are suspended for two days in a drying-room heated to about 112° Fahr., and then passed into a hot concentrated bath of chalk. As there is a large proportion of undecomposed alum on the cloth, and the base of which only becomes adherent by the intervention of saturating substances, if the goods were unequally immersed in this bath, there would necessarily follow infiltrations and flowings, producing belts or lines which would entirely destroy the beauty of a fine red ground. Care must, therefore, be taken to avoid this. The mordant being thoroughly fixed, the goods are washed, and present a fawn-colored appearance.

The Dyeing.—The dyeing is performed on ten pieces at a time, with proportions of madder which vary according to the breadth and length of the pieces, from thirteen, fifteen, seventeen, to twenty pounds a-piece. As in the preceding process, the madder is divided into two equal portions. That which is to serve for the first maddering is mixed with the quantity of water required—330 to 400 gallons—and the ten pieces are introduced into this bath, brought to a tepid state, and are kept in it three hours, progressively raising the temperature during two hours and three-quarters, till the bath arrives at a state of ebullition, which is not to be continued more than a quarter of an hour. On coming out of this bath, the fabric is washed, then submitted to the action of the cleansing machines, rinsed, and dried.

Second Galling or Aluming.—After this first maddering, steep again in the gallo-aluminous preparation; dry, and pass into the chalk bath, as after the first galling.

Second Dyeing.—This dyeing is performed in the same manner as the first, but without the addition of chalk, enough of which remains in the goods.

First Clearing.—This first clearing, as well as those that follow, is performed in the close boiler, filled two-thirds with water, containing in solution—

13 pounds of soap,
3½ pounds carbonate of potassa.

The boiling must be continued eight hours.

Second Clearing.—This is done with—

14½ pounds of soap,
14 ounces chloride of tin.

Third Clearing.—Same as the foregoing.

After this third clearing, which is only required for very lively reds, the goods are exposed for some time to the air; and after this exposure are worked through a bran bath, which exalts the brightness of the color. The red is then finished.

The process which has just been described is slightly modified by some French dyers; thus, as a long experience has proved that the oil is better fixed in the stuff when the drying is not performed too rapidly, there are some who, when the season does not admit of exposing the goods to the air, heap the pieces together, after the oiling, in a drying-room heated to 95° Fahr., taking the precaution to turn them over from time to time to prevent their becoming heated to an injurious extent. Some French dyers also have introduced the use of ox blood, employing it in the proportion of forty pounds to one hundred pounds of madder.

Persoz gives the subjoined process, as one which had long been employed with success by M. Fries of Guebwiller:—

The cottons to be dyed were lixiviated in lime, passed into acid at 1·2° Twaddle, washed in the dash-wheel, submitted to the action of a lie of carbonate of soda, containing fifty-three pounds of the soda salt to eight hundred and eighty pounds of the cotton, and lastly, again washed and dried.

For the treatment of one hundred pieces of calico of forty yards in length, or about four thousand yards, two large wooden vessels, A, B, were used, each of one hundred and ten gallons capacity. Ninety gallons of water, holding in solution thirty-six pounds of carbonate of potassa, were introduced into the vessel, A, and into the vessel, B, one hundred and ninety pounds of fat oil, slightly heated if in winter, and to which the alkaline liquor of the vessel, A, was added by small portions at a time, and carefully stirring till the oil formed a perfect emulsion. The pieces were then padded in this emulsion, and if the operation was conducted with care, the quantity of white liquor formed was sufficient for the one hundred pieces. These were then put into a heap till next day, or exposed on the grass in fine weather; otherwise, they were dried in a moderate heat, not exceeding 105° Fahr. On coming from the drying-room, they were padded again in a second white bath, exposed on the grass in favorable weather, or, if the weather was unfavourable, put again into the drying-room—heated this time to 113° or 115° Fahr.

These two white baths having been given, what remained of the liquid in the vessel, B, was poured into the vessel, A, which was filled up with water proceeding from the operation for removing the superfluous oil, or, in default of that, with water holding in solution carbonate of potassa, marking 1·2° Twaddle; in this species of white liquor the goods were worked five or six times successively, taking care to expose them on the field after each operation; they were then put into the drying-room, gradually raising the heat, but not to exceed 120° Fahr.; after the last immersion, they were kept in the drying-room for eighteen to twenty hours, at a temperature of 100° to 120°.

The Degraissage.—This operation for removing the superfluous oil was performed as follows:—On withdrawing the goods from the stove, they were put into a vessel, and sprinkled with enough of tepid water—at 90° Fahr.—to wet them thoroughly; a workman with wooden shoes then tramped them well, turning them over three or four times to multiply the points of contact, and lastly wrung them, carefully collecting the lactescent water so expressed. This is termed *the water of degraissage.* After this operation, the goods were submitted to the action of cleansing machines, in which they were rinsed till the water came out perfectly clear. They were then dried, to receive the galling or mordanting in the next process.

First Galling.—Fifty-five pounds of nutgalls were boiled four hours in forty-four gallons of water, and the decoction left to settle. The clear portion was then taken, and enough of water added to it to form one hundred and ten gallons, dissolving in this decoction—

110 pounds of purified alum, and
8 pounds of acetate of lead.

The goods were put into the padding machine in this gallo-aluminous decoction, used hot, but taking the precaution not to give too much pressure. When thus padded with mordant, they were exposed in a drying chamber to a moderate temperature, where they were left at rest three days, and afterwards passed into a chalk bath at 90° Fahr. This last operation was performed in a tub on four pieces at a time, to which four double turns were given, employing for the first four pieces four and a half pounds of chalk, and only two and a quarter pounds for each of the other four. Nevertheless, to prevent the accumulation of too much chalk in the bath, it ought to be renewed after passing twenty-four pieces through it. On coming out of the bath, the goods are washed in the dash-wheel.

First Maddering.—For eight pieces of forty yards in length, the bath contained—

70 pounds of Palus madder,
4½ pounds of Sicilian sumach.

The temperature of the madder bath was regulated so as to reach 212° in two hours and a half, and was kept at this temperature one hour, which gave for the duration of the dyeing three hours and a half. After the maddering, the goods were rinsed, carefully scoured, and dried in the air or on the grass.

Second Galling or Aluming.—In this operation the process of the first galling was exactly repeated; the mordant was the same; the only precaution to be taken was, not to work the goods at too high a temperature: it should be such that the hand may be held in the solution without inconvenience. The goods were then left at rest three days; then passed into chalk, and rinsed without scouring.

Second Maddering.—This was given like the first, and followed by a rinsing in running water.

First Clearing or Brightening.—In a covered boiler, containing three hundred and thirty gallons of water, the following ingredients were dissolved:—

17½ pounds of carbonate of potassa,
4½ pounds of white soap.

Ten pieces, oiled and maddered, were put into this liquid, kept at boil five hours, and, on being taken out, rinsed in running water.

Second Brightening.—Still using the same covered boiler, the same number of pieces were put into a similar quantity of water with these ingredients—

17½ pounds of soap,
3⅓ pounds of carbonate of potassa,
1 pound of chloride of tin.

This liquid was brought to ebullition, and kept in that state five or six hours.

Third Brightening.—In the same quantity of water were put only—

9 pounds of soap,
14 ounces of carbonate of potassa,
14 ounces of chloride of tin.

After five hours' ebullition, the goods were taken out of the covered boiler, scoured with the washing machines, and exposed on the grass eight to ten days, turning them over three or four times daily.

When the cloth which had passed through these different operations was intended to be sent into the market with a plain ground, it was passed into a water slightly acidulated with hydrochloric acid, and then rinsed.

When the goods to be brightened were sparingly oiled, they received only two brightenings—the first with nine pounds of soap, and five and a half pounds of carbonate of potassa; the second, with ten pounds of soap, and fourteen ounces of chloride of tin.

Such was the course followed and the proportions of ingredients used for a first portion of the goods; for the remaining portions the quantity of oil was diminished, and also that of the carbonate of potassa, in consequence of using the waters of *degraissage* from the preceding operations. The quantities employed were therefore—

For the second portion,........35½ pounds of oil,
For the third portion,.........33 " "
For the fourth portion,........28½ " "

adding to the water of the vessel, A, one and a half ounces carbonate of potassa for each pound of oil introduced into the vessel, B.

The two preceding processes for dyeing Turkey-red differ only in the degree of temperature at which the desiccation is performed, in the quantity of acetate of lead added to the alum to give it a greater tendency to fix itself on the stuff, and, lastly, in the addition of sumach to the madder bath. These differences, however trifling they may appear, often lead in practice to results, the importance of which entitles them to consideration.

SWISS TURKEY-RED PROCESS.—Switzerland has long enjoyed a merited celebrity for its Turkey-reds, having been enabled, by the application of superior intelligence to the subject, to struggle successfully against unfavorable conditions, and to send into the market products which bear advantageous comparison with those of any other country, both in regard to price and quality. This success, says PERSOZ, may be attributed to the great reduction which has been effected by the dyers of that country in the quantity of oil and weight of madder employed. The quantity of oil formerly used was at least equal to half the weight of the cotton, whereas it is now reduced to a fourth; and the madder used, from being double the weight of the cotton, is now reduced by many dyers to the same weight—

that is to say, one hundred pounds of madder, instead of two hundred pounds as formerly, are now taken for dyeing one hundred pounds of cotton; and yet the results leave nothing to desire.

There is not anything essentially new in the process followed in Switzerland; its excellence consists only in the application of several scattered data, the uniting of which in the same process conduces to results of the most satisfactory character. It is to the same circumstance that Eberfield owes the superiority of its products in this department of dyeing.

Oiling.—In the process commonly followed in Switzerland, the white baths are given at a temperature of 80° to 85° Fahr., adding to the ingredients, already stated as used in the French process, cow dung in a state of fermentation.

For a portion consisting of two hundred kilogrammes, or four hundred and forty pounds, of cotton, the following ingredients are employed:—

29½ pounds of fat oil,
55 gallons of carbonate of potassa, in solution, at 39·2° Twaddle.
13½ gallons of cow dung, fermented, and brought into a pulpy state with a little cow urine.

The cow dung is mixed with fifty and a half gallons of water heated to 98° or 100° Fahr., the oil is added, and the whole is formed into an emulsion by introducing, in successive portions, four and a half gallons of carbonate of potassa in solution, at 39·2° Twaddle. The temperature of the liquid being then brought to the desired point, the goods are padded in the usual manner. They are then introduced into a wooden trough, in which they are left to themselves from twelve to eighteen hours to set up a fermentation, which is often carried to such an extent, that it is not a rare occurrence to see myriads of small worms developed in that short period. They are then dried in the open air, and exposed during eight or ten hours in a stove heated to 145° Fahr.

After this first bath, they receive a second, a third, and a fourth, always fresh prepared, adding to the residue of each of them the proportions indicated above, so that, after these four oilings, the four hundred and forty pounds of cotton have consumed—

117½ pounds of oil,
220 gallons of carbonate solution,
54½ gallons of cow dung;

and after each bath, the goods are exposed, first to the air, and then in the stove heated to 145°.

These four oilings are followed by other four, performed in the same manner, but in tepid water, holding in suspension the residues of the four original white baths, and the *old liquors* from the *degraissage.* After each of these immersions, they are dried in the open air and stoved, as after each passage through the white bath, but at lower temperatures—namely, at 140° Fahr. after the fifth and sixth baths, and about 132° after the seventh and eighth, with which this operation is concluded.

The next process is the *degraissage* or *unoiling*, by the method indicated in M. FRIES' process. The *old liquor* is collected during this operation, and the goods are then cleaned by the dash-wheel, from which they are taken out to be wrung, and then dried in the stove at the temperature of 120° Fahr.

Galling.—The galling is also performed in two operations; for the first, in which no alum is used, the following ingredients are boiled for one hour in forty-four gallons of water:—

16½ pounds gall-nuts,
14 pounds Sicilian sumach.

To allow this decoction to clear, it is left to itself for twenty-four hours after passing it through the sieve; then decanted and heated to 110° Fahr. The goods are then padded with this liquor, dried in the open air, and afterwards stoved at the temperature of 120°

The second galling is performed exactly in the same manner as the first, except that the sumach is kept back and alum added.

In forty-eight and a half gallons of water heated to 115°, dissolve—

47 pounds of purified alum, saturated with
77 pounds of carbonate of potassa, in solution, at 39·2° Twaddle.

After passing the goods through this bath, they are wrung or pressed out, and left in a heap during six hours; they are then put into the stove—heated to 80°—to be dried, without a current of air; they are next *ventilated* for three days, and afterwards passed through the stove heated to 120°. Then, as the alum is only partly saturated, they are passed through a chalk steep raised to the temperature of 120°, using five and one-fifth pounds of chalk for forty pounds of cloth. When rinsed and dried after coming out of this bath, the goods are ready for dyeing.

The Dyeing.—This is performed in one operation, taking for forty-four pounds of the fabric from

44 to 66 pounds Palus madder,
6 pounds sumach,
3·74 gallons ox blood.

The temperature of the bath is progressively raised during two hours and a half, and the boiling is kept up half an hour; the pieces are then rinsed, and submitted to two brightenings, which they receive in the covered boiler, where they are boiled six hours, namely:—

For the first operation, with eleven pounds of soap, sixty-six pounds of carbonate of potassa, and forty-four pounds of chloride of tin.

For the second brightening, with eleven pounds of soap, forty-four pounds of chloride of tin, and two hundred and eighty-six pounds of nitric acid.

After these brightenings, the goods are exposed on the grass for two or three days, and then passed into a boiling bran bath.

This process is essentially distinguished from the preceding ones, inasmuch as all the operations tend to provoke a fermentation among the different substances which are found in presence of each other, and to determine the metamorphosis of the fatty body. While recognising the necessity of reaching a certain degree of heat, it evinces, at the same time, a full appreciation of the importance of giving due scope to the action of the air. This action is exerted so much the better on the cotton in proportion as the latter contains a certain quantity of water, whilst a too rapid drying withdraws it from the influence of the agent which is called to perform the principal part in the reaction. It is doubt less for this reason that the dryings in the stove-chamber are always preceded by exposures in the open air, which only produce a slow desiccation.

TURKEY-RED PROCESS WITH NITRIC ACID.—In the process which has just been detailed, a small portion of nitric acid is used in the brightening; but in that which follows, it enters in considerable quantity into the oiling. This process has been used with good results by M. GASTARD, to whom dyers are indebted for the direct application of the coloring matter of madder. The following are the details of his method, as communicated by that gentleman to M. PERSOZ:—

Preparation of the Goods.—After leaving the goods for a period of twenty-four hours in water heated to 70° or 80° Fahr., they are worked through it, and then boiled four hours in water containing sixty-six to seventy gallons of old white liquor; they are left in the same boiler till next day, when they are again well sodden, rinsed twice, and dried.

For sixty pieces of cotton weighing two hundred and thirty-three to two hundred and forty pounds, the white bath is composed as follows:—

7·7 pounds of fat oil,
2·6 gallons of sheep or cow dung.

Oiling.—With the substances above-mentioned, incorporate a solution of carbonate of potassa at 5·4° Twaddle, till a perfect emulsion is produced, sufficient to impregnate the whole of the fabric. Pad the pieces in this emulsion, expose them to the air in the sun, if the weather permit; if not, hang them up to dry. When the desiccation is nearly finished, introduce them for four or five hours into the drying stove, heated to 150° or 160° Fahr.; on coming out of the stove, they are twice worked through water, acidulated with nitric acid at 1·2° Twaddle, and then dried in the air, but not now in the hot stove, where they would infallibly be burned. They afterwards receive—

1. A second white bath like the first, followed by exposure to the air and in the hot stove;
2. A second passage through nitric acid at 1·2° Twaddle, followed by a desiccation in the open air;
3. A third white bath similar to the first, and followed in like manner by an exposure to the air and in the hot stove;
4. A third passage through nitric acid at 1·8° Twaddle, followed by a desiccation in the open air;
5. A fourth white bath similar to the first, followed by exposure to the air, and stoving at the temperature of 150° to 160° Fahr.;
6. A fourth and last treatment with acid, to which succeeds a desiccation in the open air.

For the last two oilings the dung may be omitted.

Degraissage.—After all these operations, the goods are passed into a solution of carbonate of potassa at 6° Twaddle; they are then wrung out, collecting the old white bath, dried in the air, left to steep in water for two hours, and, lastly, rinsed and dried twice over.

Galling.—The galling is also given in two operations: the first, in a perfectly clear decoction of thirty-three pounds of Sicily sumach; the second, in a decoction of nut-gall.

In both operations the liquor is used hot, and the two are followed by a desiccation.

First Aluming.—In the quantity of water required to impregnate these two hundred and forty pounds of cotton, dissolve—

26·8 pounds of alum, and add
1·65 pounds of acetate of lead,
4·4 gallons of solution of carbonate of potassa at 5·4° Twaddle;

pad the goods in the liquor, which should be used cold, and after it has cleared by settling, it ought to indicate 5·4° Twaddle. The goods are then laid in a heap, and left in that state twelve to fifteen hours, after which they are dried, and then put to steep in water four hours; finally, they are rinsed twice in running water.

First Maddering.—To madder the sixth part of the quantity of goods indicated, or about ten pieces, use—

37 pounds of madder,
2·2 to 2·6 gallons of ox blood,
4·4 to 7·7 pounds of sumach.

The dyeing is effected in three hours, gradually raising the liquid to the boiling point. On coming out of this bath, the goods are washed, scoured, and dried.

Second Aluming.—This aluming is performed in the same manner as the first, except that, when the goods are dried, they are passed, at the temperature of 120°, into a bath of cow dung impregnated with chalk, and then rinsed.

Second Maddering.—Same as the first.

First Brightening.—For thirty pieces, or one hundred and sixteen to one hundred and twenty pounds of the stuff under operation, pour into a boiler of suitable capacity, half-filled with water, eleven to thirteen pounds of carbonate of potassa, and sixty-six to seventy gallons of old white liquor; boil four or five hours, and leave the goods in the boiler till next day; then take them out to be rinsed and beaten; and, lastly, spread them on the grass, where they are left exposed four to five days according as the color developes.

Second Brightening.—Pour into the clearing boiler, along with the quantity of water required, a decoction of 2·2 pounds of bran; when the liquid is in full ebullition, add to it a solution of 16·5 pounds of Marseilles white soap, and then, by small portions at a time and stirring well, a solution of one pound of chloride of tin, in one gallon of water, acidulated with half a pound of hydrochloric acid, and one and a half to two ounces of nitric acid, according as it is desired to give to the fabric a more or less scarlet tint. The goods, previously wetted, are then introduced into the boiler, in which they are boiled for an hour, and left in it till next day.

PERSOZ remarks, that if chalk does not appear prominently among the agents employed in this process, this may be attributed to the circumstance that the waters employed by M. GASTARD were essentially calcareous. He calls attention, at the same time, to the fact, that the consumption of oil is greatly reduced by this method, since thirty pounds of that substance suffice for the oiling of two hundred and forty pounds of cotton; and what is remarkable, he affirms that, notwithstanding the small quantity of fatty matter employed, he found the results fit to be compared with the finest samples produced by the ordinary methods.

VIOLETS ON THE TURKEY-RED SYSTEM.—By mordanting the oiled goods with an iron, instead of an aluminous mordant, violets of great beauty and peculiar lustre are obtained. For this color, it seems to be essential to employ sheep dung, and to pad the cloth with an iron mordant at its maximum of oxidation; the nitro-sulphate is used for this purpose. **PERSOZ** affirms, as the result of his own experience, that very fine violets may be obtained by mordanting the oiled goods in a solution of ferric-sulphate, obtained from the calcination of ferrous-sulphate, and marking 4° Twaddle, mixed with 7 to 8 per cent. of chloride of ammonium. On coming out of this bath, the goods are dried, then passed into another bath of arseniate of lime and potassa, as in fixing ordinary mordants.

RATIONALE OF THE TURKEY-RED PROCESS.—This process is far too important to be passed over without some attempt to explain the action of the different ingredients employed, which result in producing the most beautiful and permanent of dyes. One of the highest authorities on this subject is M. **PERSOZ**, and therefore the Editor cannot do better than subjoin a summary of the observations of that eminent practical chemist on the different parts of the process.

First, with reference to the *oiling*, **PERSOZ** remarks that to oil the goods for this purpose, it is not sufficient to cover them with some fatty body, since experience proves that a spot of oil or grease, which is not modified in some manner, acts as a resist or reserve on the part of the stuff which it covers, and prevents the mordants of iron or alumina from adhering to it. The nature of this body must therefore be modified by the aid of alkalies or alkaline compounds, under the threefold influence of water, heat, and air. Nevertheless, there is not in this case a simple saponification, as some have maintained; for if so, it would be sufficient to use soaps having for their base olive or common oil, to impregnate the fabric with these, and then to set the fatty acids at liberty, in order to bring the goods to a state capable of being dyed a rose color in a madder bath. But this is not the case, for the oiling operation never succeeds better than when carbonate or bicarbonate of potassa or soda is used, the saponifying action of which substances at the common temperature is not to be compared with that of caustic alkalies. The cause must therefore be sought in another direction. The oil and the bicarbonates are doubtless the principal substances of this operation; but the former must not be a drying oil—it must be of that kind which is termed in commerce *fat oil*, and use must be made of certain matters, such as sheep or cow dung, which it has not been found possible to dispense with. Gallipoli oil is generally used in this country; that employed on the Continent is of the same nature, and is termed in France *huile tournante*, from its tendency to become rancid, and from the circumstance that, when mixed with a solution of carbonate of potassa or soda, it immediately produces a milky emulsion, colored slightly yellow. These oils are obtained from olives which, before being pressed, are submitted to the action of hot water, and are consequently strongly charged with extractive matters.

After being padded with the white liquor, consisting of a mixture of the fat oil, bicarbonate of soda or potassa, and excrementitious matter, the goods are dried, as has been stated, either by exposure to the sun, or in the hot stove. During this drying process the fatty body experiences a modification which renders it insoluble in weak alkalies, and acquires in a very high degree the property of strongly adhering to the fabric; but, as this modification begins at the surface of the goods, and the external portion of each coating of the white liquor is easily detached, not having entered into combination with the stuff, the operation of passing through the white bath is repeated till the fabric is sufficiently impregnated with the oil. The number of passages through the white liquor is regulated both by the season and the temperature of the stove in which the goods are dried, as well as by the nature of the oil employed. Formerly, eight to fourteen baths were given; the number is now much reduced.

The heat of the sun and of the weather exercises a very great influence on the goods when dried in the air. In autumn, in winter, and in spring, much more difficulty is experienced than during the summer season in modifying and fixing the fatty substance. When the goods are exposed in a drying chamber, the effects of the artificial heat are not less marked, and if the proper temperature is not attained, important differences are observed in the intensity of the shades produced.

The modification which the fatty substance undergoes when it is submitted, in contact with the fabric, to the threefold influence of the air, of heat, of the alkaline carbonates—the products into which it is metamorphosed—in a word, the rationale of this mysterious operation—have not been satisfactorily explained. **PERSOZ** remarks that there is no question more profoundly interesting to the chemist, and that to the importance which it presents in a theoretical point of view may be added the practical consideration, that he who should succeed in discovering a method of modifying at pleasure fatty bodies of this nature, could not fail to realize a very large fortune by the discovery. M. **WEISSBERGER**, one of **PERSOZ**'s pupils, found that the oiled stuffs, which give up their modified fatty substance to oil of turpentine, yield it also to acetone; and by availing himself of this property, and afterwards evaporating the acetone in the water-bath, he found as the residue a viscous liquid of a fatty nature, which separated itself into two strata, the one solid, the other liquid, and capable of being kept a long time in the same state. The modified fatty substance having been extracted by the acetone from the cloth which had passed through the white bath, M. **WEISSBERGER** ascertained that, in proportion as this substance was abstracted, the cloth lost its power of attracting and combining with the madder dye. Desirous of knowing whether this viscous liquid still possessed the essential property of the fatty body by which it was generated, he saponified it with powerful bases, and finding no trace of glycerin in the products of the saponification, he was forced to conclude that this substance had disappeared. Lastly, he showed, and M. **PERSOZ** himself repeated and verified the experiment several times, that it was only necessary to apply on a stuff, a suitable quantity of this modified fatty body, so abstracted by acetone, to obtain with the madder the deepest and purest shades; and from his experiments on this subject, M. PERSOZ concludes, that if one ever succeeds in preparing this fatty body directly, the use of the aluminous mordants may be dispensed with. This observation, says that chemist, which seems at first rather extraordinary, is supported by another made by M. CHEVREUL on a particular *Turkey-red* which he analysed, and from which he could only extract a very small quantity of alumina, although a large proportion of that substance had been used in the dyeing process. If the glycerin disappears in this operation, it is by undergoing an oxidation and a transformation, the former being produced by the united action of the air and the conditions of temperature at which the oiling is performed; the latter by the use of azotised substances indispensable for putting the organic matter in motion. M. PERSOZ thinks, that to these substances must, doubtless, be attributed in great part the necessity of using excrementitious matters; he conceives also that the phosphates which exist in the latter in considerable quantity, may exercise an important influence.

The object of the alkaline washing, which follows the white baths, is to remove that portion of the fatty body which has not undergone the requisite modification, and also that portion which, although modified, is not in a state of adherence to the fabric; for if these portions of the organic mordant were not removed, the inorganic mordant next applied would not be fixed on the goods in an equal and uniform manner, in consequence of the unmodified fatty substance acting the part of a resist.

It is generally ackowledged that in the process of oiling, the fatty body is better modified and fixed on the stuff, in proportion as the latter is longer exposed to the air with the humid oily preparation upon it, but under protection from the rain and the too powerful action of the solar rays, and also in proportion as the stoving is conducted at the proper temperature. It appears best to impregnate the fibre only at its surface, for otherwise the shade becomes too deep, and it is difficult to pass it through the brightening process without diminishing the liveliness of the tint. By cutting a piece of cloth which has been dyed the finest red, it will be seen that the interior of the fibre is white, which proves that the oil and the aluminous mordant penetrate only imperfectly into the centre. This application of the color to the surface of the stuff gives a peculiar lustre to the shade, which the colorless or slightly colored interior of the cloth naturally renders clearer and more transparent.

When the goods have been oiled, great care must be taken to prevent the slow or spontaneous combustion of the fatty body with which the stuff is charged: in the former case, the fabric is always more or less injured; in the latter, the establishment is in danger of being set on fire—a calamity which has sometimes happened from this cause.

The slow combustion, as well as the spontaneous, proceeds either from too much oil in the stuff, or from too little carbonate of potassa having been employed to saturate it. The first is determined by the exposure of the goods in too powerful sun-heat, or by the heat which is developed from their lying too long in a heap; the second is produced by the action of the oxygen on the free oil which covers the goods when in the stove. Turkey-red dyers, who employed, in other respects with success, drying oils from seeds, were compelled to give up the use of such oils in consequence of the accidents of this kind to which they led.

As it is demonstrated by BOUSSINGAULT'S experiments, that cow urine contains alkaline bicarbonate, it might be worth trying whether this substance might not be successfully applied for the oiling of goods. It contains, likewise, principles essentially fermentable, and would therefore be better fitted to play the part of a ferment, than the water charged with alkali which is used at present. In connection with this subject, PERSOZ expresses his belief that cow dung may act in virtue of the fatty body which it contains, and that the nourishment given to the cow may produce a sensible effect on the operations in which that excrement is used, by modifying the nature of the fatty body contained in it, and which will vary with the kind and age of the herbage on which the animal is fed.

Thus much with reference to the *oiling*, or the organic mordanting, which constitutes the special characteristic of the Turkey-red process. The next subject to be considered is the *real mordanting*, or the application of the inorganic substances. When the goods have been perfectly scoured after the oiling operations, which is known by wringing them at one end, and observing whether the water comes out perfectly clear, they are covered evenly over with inorganic mordant. Alum or acetate of alumina is used for red mordant, nitro-sulphate of iron for violet mordant; but these preparations do not perform what is required of them in the same conditions, for the affinity of the modified fatty bodies for alumina, however great it may be, is yet insufficient to determine the total decomposition of the alum, and the complete fixation of its base on the stuff, for which purpose it requires to be saturated. Hence, while some dyers are satisfied with padding their goods in acetate of alumina, to give them the proportion of that base necessary for the fixation of the coloring matters, those who use only alum—the general practice in this country—must necessarily interpose other bodies to favor the adherence of the alumina to the stuff. They have, therefore, recourse to galling, perhaps without being aware of its use, although it is in fact a preliminary operation to which all goods were formerly submitted that required to be mordanted. It follows that there are two methods of mordanting, one of which consists in padding the goods purely and simply with acetate of alumina, the other in impregnating them with a decoction of nutgall or sumach, an operation properly termed *galling*, and which is most generally confounded with that of aluming, by previously making an astringent decoction which should mark from 11° to 12° Twaddle, and in which the alum is dissolved. M. DANIEL KOECHLIN, who used acetate of alumina, arrived at the conviction that the interposition of the nutgall has no influence on the shade of the red; its only advantage, he believed, was in giving the color more solidity, especially when the goods have to pass into a solution of bleaching powder. When padded with the gallo-aluminous solution, they are dried and passed into a chalk bath, to saturate the alum, and render it cubical, so as to be capable of yielding up its base to the stuff. It is remarkable, says PERSOZ, that the alum is not first saturated with the chalk, which, being absorbed in large quantity, would form a very soluble compound, yielding the alumina readily to the goods. When acetate of alumina is used, the mordanted cloth is dunged in the usual manner, and then passed through a dilute chalk liquor.

The next process is the *dyeing* or *maddering*, which is not performed in precisely the same manner in all establishments. In some it is done at one operation, in others at two; the first dyeing is termed in France the *retirage*, and the second *bouillissage*. Again, the proportions of madder required vary between a quantity equal to the weight of cotton employed and twice that quantity, along with a certain proportion of chalk. It is impossible, says PERSOZ, to obtain fine rose tints which have no tendency to pass to a violet shade, without the intervention of this last-named substance. The effect of lime has long been known to give a peculiar beauty and durability to colors.

Independently of the chalk, a certain quantity of sumach is often mixed with the red, to economise the madder. It results, in fact, from the experiments of J. M. HAUSSMANN, that an addition of sumach and nutgall to the madder bath contributes to the development of a much larger quantity of coloring matter. But M. EDOUARD SCHWARTZ, who has corroborated this advantage, so far as regards the amount of color produced, is convinced that the reds dyed in this manner are infinitely less fixed, and consequently ill fitted for those styles which required to be passed through the chloride of lime liquor.

Besides the sumach, bullocks' blood, in the proportion of one-fourth of the madder employed, is sometimes added to the madder bath; or a certain quantity of Cologne glue, which is mixed with the sumach in equal parts, and amounts to the fourth part of the madder.

In some dye-houses the maddering is performed over an open fire, in others the vessels are heated by steam; but as, for this kind of dyeing, the temperature must be kept at the boiling point, and there is a large condensation of water, some dyers have recourse to a convoluted pipe for circulating the steam to heat the bath.

The *brightening* constitutes the last series of operations, and these will be considered first with reference to the agents employed, and secondly as regards the apparatus required.

The brightening or clearing of Turkey-red differs essentially from that of ordinary reds, in this respect, namely, that for common reds, the first operations tend chiefly to fix the fatty body of the soap, and to render it a constituent part of the lake which is formed at the surface of the stuff, to give it in this way all the stability and vivacity possible; whereas, in the brightening of Turkey-red, the fabric being saturated with fatty matter, the effect to be produced consists, first, in removing the excess of that fatty matter, and secondly, in substituting for the alumina—the base of the red lake—a certain quantity of oxide of tin, which modifies its shade and gives it that fiery tint which is characteristic of the Turkey-red, and is so opposite to that of the common red, which inclines to amaranth.

The substances which serve for the brightening are carbonate of potassa, soap, and chloride of tin. Generally, the soap and carbonate only are used for the first brightening, and the chloride of tin is introduced in those that follow. After the first operation, the soap and chloride of tin are alone employed. The part performed by these substances is easily understood: the carbonate of potassa and soap effect the solution of the fatty body in excess, and dissolve at the same time a pretty large proportion of the coloring matter which is found remaining in the bath. As regards the chloride of tin, it undergoes decomposition, and oxide of tin is produced, which displaces a portion of aluminous oxide, takes its place, becomes oxidized, and converts the red into a fiery shade, by reason of the orange tint which the compounds of tin assume in the madder bath.

PERSOZ suggests that soap might be dispensed with in the first brightening, and its place supplied by carbonate of potassa at the pressure of half an atmosphere. This salt does not injure the fabric, and furnishes very fine colors. It might also be useful to attend to the observation made by M. E. SCHWARTZ, that on treating with a concentrated solution of bleaching powder a small piece of Turkey-red which had just been dyed in the madder bath, an orange-red was obtained which had no analogy with that produced by the ordinary brightenings, whilst a similar piece, treated hot in the same solution, previously decomposed by carbonate of soda, gives, if the proportions have been well observed, a red as fine as that which has been brightened with soap.

It is known that, in the clearing or brightening of common reds, the treatments with soap produce no favorable effect beyond certain limits, the lake being supersaturated with fatty matter, and that, to render them more efficacious, the action of air or acids must be brought to bear. Now, the red upon oiled goods is precisely in the same state of supersaturation when submitted to the brightening process; would it not be desirable, therefore, on taking the stuffs from the madder bath, to treat them immediately with acids, and only to apply soap in the last place? It is perhaps to something of this kind that one may attribute the advantages which some dyers have found from impregnating the oiled goods with weak nitric acid.

When, after the clearing operations, the red assumes a rose shade, this is a proof that the cotton has not been sufficiently saturated with oil, or that the quality of this oil has not been suitable, or that the white baths have been mismanaged, or, lastly, that the desiccations have not been performed at the temperature required for the modification of the fatty body.

With reference to the apparatus used in the brightening processes, the liquor is heated in a covered boiler of about two hundred and twenty to two hundred and sixty gallons capacity, containing, with the requisite quantity of water and soap, any amount up to seven hundred yards of cotton goods, oiled and maddered; they are left to boil under a certain pressure from twelve to eighteen hours, and are brightened a second or even a third time, according to the degree of intensity which it is desired that the red should possess.

To avoid the loss of steam which results from the daily use of the common covered boiler, **Schwartz** has proposed a new arrangement for economising the waste steam. This arrangement is shown in Fig. 351. Contiguous to the common boiler, A, is placed another, B, which communicates with the former by means of a jointed tube, P, fitted with a stopcock, I, by which the steam disengaged from the boiler, A, passes into the boiler, B, under the false copper bottom, D. This false bottom is perforated like a colander, and rests on the support, E, on which the goods in this boiler are placed. Both boilers are furnished with safety-valves, M, M, with discharge-cocks for the steam, N, N, and with stopcocks below for discharging the fluid contents.

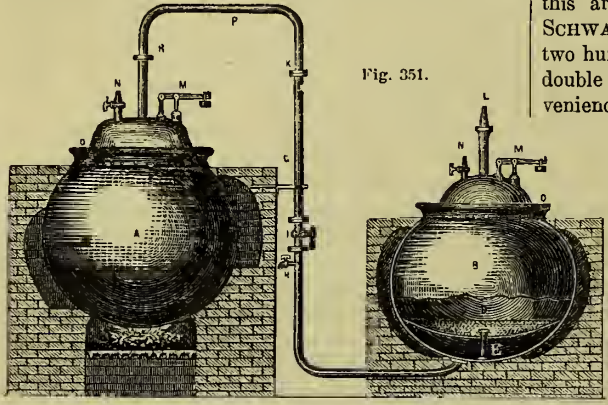


Fig. 351.

O is a flange, which, by arresting the water of condensation that runs down the lid, prevents it from falling on the heated sides of the boilers. The object of the stopcock, H, is to second the operation of the safety-valve, and to enable the attendant to watch the progress of the operation. When steam escapes on the opening of the stopcock, all is right; but when water comes out, this is a proof that a valve which is placed at R is not working, and that the steam must make a passage for itself by the safety-valve.

It is easy to work these boilers. When the quantity of water required for one operation has been pumped into the boiler, A, and brought to ebullition, the agents employed in the brightening process, and the quantity of goods to be subjected to their action, are introduced; the lid is then fixed on, with the pipe, P, attached to it, carrying at the joining, R, a valve which opens upward. The stopcock, I, is then opened, and the steam which passes into the boiler, B, brings the liquid in that boiler to ebullition in the space of three hours. The latter is then charged in the same manner as the first boiler, covered over, and the steam allowed to enter during seven hours. The goods in the generating vessel thus receive a boiling of ten hours; those in the other only seven hours. When the boiler, A, ceases to give out steam, the valve of the boiler, B, is shut, that no steam may be lost. The latter preserves so much heat that the goods may be left in it two hours longer, at the end of which period it has still a certain pressure. And as it is the custom to give a shorter time to the goods at the second and third brightening, the boiler, A, is specially employed for the first operations, which are kept up longer, and the boiler, B, for what is properly called the *rosing*.

Besides the advantage attending the circumstance that old copper vessels may be employed for the boilers, B, which do not receive the direct action of the fire, this arrangement affords a great economy of fuel. **Schwartz** attributes to it a saving to himself of two hundred and seventy pounds of coal daily. This double boiler system is not, however, without its inconveniences; it entails the necessity of preventing the condensation of the steam, especially in cold weather, by surrounding the boiler, B, with some non-conducting substance, such as powdered charcoal.

During the process of brightening, great care must be taken that the tube and safety-valve do not get out of order; negligence in these matters has often produced heavy losses, and sometimes even the death of the workmen engaged in conducting the operation.

Such is a general review of the process of dyeing Turkey-red, as conducted in almost all the establishments in which it is carried on, both on the Continent and in this country. Another process was proposed by J. M. **Haussmann**, which differs in some important particulars from any of the common methods; and therefore, though never applied on a very large scale, a short account of it may be useful. It consisted in dissolving one part alum in two parts warm water, and while in a state of ebullition introducing into this liquor enough of concentrated caustic potassa lie, to precipitate and redissolve the alumina of the alum. By cooling and allowing to settle, a great part of the sulphate of potassa was deposited, and the clear liquor being decanted off, he added, by small portions at a time, to thirty-three parts of this solution of alumina and potassa, one part of linseed oil, thereby forming an emulsion with which the goods were impregnated. The cotton, thus prepared, was dried under shelter from the rain in summer, and in winter in a hot chamber; after twenty-four hours they were rinsed and again dried; then they were padded in the alkaline emulsion a second time, quickly dried in the air, and so on till the stuff had received the number of emulsions required. M. **Haussmann** said that two impregnations of the alkaline solution of alumina mixed with linseed oil, sufficed for obtaining a fine red; but by continuing to impregnate the goods a second and even a fourth time under the same conditions as the first, the colors were obtained extremely brilliant.

By this process he oiled and mordanted his cottons at one operation, and had only then to proceed with the dyeing, which was performed in this case also with the addition of a quantity of chalk equal to one-sixth of the weight of the madder, and using thirty or forty times that weight of water. The dyeing was performed differently from the usual manner. He brought the bath gradually during the space of an hour to such a temperature as just admitted of the hand being held in it without inconvenience; he then left the cotton in it two hours longer, which gave a duration of three hours to the operation. After the dyeing, the stuff, being thoroughly washed and scoured, was passed through a bran bath, adding to it soap and carbonate of potassa, when it was desired that the goods should have a crimson-rose shade. HAUSSMANN affirmed that he obtained by this process reds which surpassed in beauty and brilliance those of the Levant, and which could in all respects bear comparison with even the best that were produced in France. His son, M. B. HAUSSMANN, entirely corroborated to M. PERSOZ all that had been stated by his father with reference to this process, but acknowledged, at the same time, that no extensive application had been made of it, because the results had never been favorable on a certain scale. This, to say the least, appears somewhat unintelligible.

Oiled Rose Grounds.—Besides the red and violet grounds obtained by the preceding processes, rose grounds are also given to oiled stuffs. For this purpose, after oiling the goods as equally as possible, and in the same way as for reds, suppressing sometimes one or two of the oilings, and then subjecting the goods to the usual *degraissage* process, two methods are followed. Some dyers then pass them into a very weak aluminous mordant, scour and dye in madder in the usual way; others, who by this method obtain weaker but much purer shades, put them directly into the boiler, in which they brighten the goods for red shades. The coloring matter that has been detached from the latter is found sufficient to saturate the organic mordant, and to give it the desired tint. For pale colors no process can be better; for if the cloth be saturated with oil, the quantity of aluminous mordant employed will always be too great, however weak it may be, and the shade will always be too deep. Now, to degrade it, would be to destroy its lustre, while, if the oiling be diminished, the tints will return more or less to ordinary reds, and will not stand the brightenings which are indispensable to bring them to the natural tone of the Turkey-red.

It now remains to add to the preceding details and explanations of the Turkey-red process, the following ingenious views on the subject, by Mr. JOHN THOMPSON of Glasgow, which first appeared in the eighth volume of the Annals of Philosophy, and which, in conjunction with M. PERSOZ's speculations already given, afford, perhaps, all the light that can be thrown on what Dr. BANCROFT termed, in 1794, an unaccountable process which chemical analysis does not elucidate:—

Silk and worsted, says Mr. THOMPSON, have a natural varnish which cotton does not possess. To supply this defect, the repeated immersions, followed by exposure to the atmosphere and to the heated air of a stove, may give the oil the proper consistency, by the absorption of oxygen, for forming a varnish, with which the coloring matter unites, and through which it may be said to shine, which causes that superior brilliancy which the goods attain when they are cleared, or, as it may be called, polished. He therefore presumes that the fixedness and brilliancy of the color will depend on the quantity of oil imbibed, as every repetition of drying presents new fibres to be varnished with an additional quantity; for he has always found that the permanency was in proportion to the number of manipulations in the saponaceous liquor, and a proportionable freedom could also be used in reducing or clearing. The white immersions, omitting the sheep's dung, are just applying successive coats of varnish. Clearing is never attempted from the madder copper, without immersing the goods again in soda and oil, and drying them in a stove, which is considered to be also supplying them with an additional coat.

The alkaline lie occasions a greater separation in the particles of the oil, by which it combines more closely with the fabric of the cloth. The sheep's dung in the first immersions may serve as a covering or great-coat, to keep the goods moist for a considerable time, that they may more fully imbibe the liquor, by preventing the evaporation from being too quick in the great heat to which they are exposed.

After the frequent immersions the cloth feels like leather, no doubt from a superfluity of liquor. It is then steeped in a lie of carbonate of soda, and afterwards well washed and dried, as a preparation for the galling and aluming. The astringent principle has been long known for darkening and fixing common red colors on cotton, by uniting with the earth of alum, and strengthening the basis. To the use of blood in the madder copper, Mr. THOMPSON attributes nothing; as in the rancid and putrid state in which he has seen it employed, were it not for the prejudice of the operator, it might be safely dispensed with.

In proof of the above idea, that it is only the oil uniting with the earth of alum that is of use, he refers to the mode of dyeing that color in the East, quoted by Dr. BANCROFT, namely, soaking their cotton in oil — no matter of what description — during the night, and exposing it to the sun and air during the day, for seven successive days, rinsing it only in running water, and then immersing it in a decoction of galls and the leaves of sumach previous to aluming.

Mr. THOMPSON, therefore, requests the practical dyer, who wishes to arrive at a knowledge of this unaccountable process, to give up the idea of animalization, if by it be meant impregnating the cloth with an animal matter, and by the power of the microscope, or any better method, look for the whole truth from some other source than chemical analysis. He is inclined to believe that it is a mechanical operation united to a chemical, and that the frequent immersions in the imperfect soap are equivalent to laying on the first, second, third, *et cetera*, coats preparatory to finishing a fine painting in oil.

CALICO-PRINTING.—*Impression d'Indiennes*, French; *Zeugdruckerei*, German.—This is, perhaps, the most important branch of industry springing from the parent stem of the cotton trade, and may be described as the art by which topical colors are impressed on cotton cloth, giving variations of form, and gradations of tint, far more cheaply and expeditiously than in the loom. Of late years, silk and woollen fabrics have been made the subjects of a similar style of dyeing, and linens were formerly stained to a greater extent than at present, with various colored designs. Cotton or calico, however, has always been the chief material employed in this department, though the common import of the term Calico Printer, in the present day, is a printer of all sorts of fabrics—calicoes, muslins, linens, silks, or woollens, or the many mixed varieties, composed of different materials.

Cotton cloth, says BAINES, in his admirable History of the Cotton Manufacture, when used for under garments, is generally worn in the white state; but when used for the outer garments of the female sex, the drapery of beds and windows, the coverings of furniture, and similar purposes, it is ornamented with colors and patterns. Unlike silk and woollen fabrics, cottons are very rarely dyed of a uniform hue throughout; a variety of colors is fixed upon a single piece, and they are printed on the white cotton or muslin in an endless variety of patterns, thus giving a light and elegant effect to the print. The art of the calico-printer, therefore, not only comprehends that of the *dyer*, which requires all the aid of chemical science, but also that of the *artist*, for the designing of tasteful and elegant patterns, that of the *engraver*, for transferring those patterns to the metal used to impress them on the cloth, and that of the *mechanician*, for the various mechanical processes of engraving and printing. *Taste*, *chemistry*, and *mechanics* have been called the three legs of calico-printing.

HISTORICAL NOTICE.—The leading events in the history of calico-printing, considered as a branch of the general art of dyeing, have been given at pages 567 and 568; but its vast importance, its rapid progress, and its intimate connection with recent chemical discoveries, will justify some further details. It has been shown that the art was of very ancient date in India, and that it derived its name from the fact, that the first material printed upon in this country was the East Indian cotton fabric, commonly known as calico. It has been seen, also, from PLINY'S testimony, that the Egyptians appear to have been conversant at a remote period with some of its most refined processes. In different parts of the East, great varieties prevail in the knowledge and skill with which this art is practised. Block-printing is wholly unknown in some parts; and BANCROFT remarks, that in India the patterns are usually, if not always, drawn with a pencil or reed, as may be inferred from the fact, that no two forms or figures in the work are exactly alike; but Mr. BUCKINGHAM states, that at Orfah, in Mesopotamia, the printers have small wooden blocks, of four to six inches square, and use them nearly in the same way as the block-printers in this country. It is well known that the Chinese employed block-printing long before any species of printing was known in Europe. The means and processes by which the art is practised in Asia Minor, Turkey, and, indeed, in all the countries of the East, clearly prove its oriental origin.

It is doubtful in what country of Europe the art of calico-printing was first introduced; but it has been previously stated, that, towards the close of the seventeenth century, Augsburg was famous for its printed linens and cottons, and therefore it must have been practised there long before its introduction into England. It is mentioned in ANDERSON'S History of Commerce, that calico-printing commenced in London in 1676. On the other hand, Mr. JAMES THOMSON, a distinguished and scientific calico-printer, near Clitheroe, stated in his evidence before a select committee of the House of Commons, in 1833, that the origin of printing in England dated from about the year 1690, when a small print ground was established on the banks of the Thames, at Richmond, by a Frenchman, who, in all probability, was a refugee, after the revocation of the edict of Nantz. Its subsequent curious legislative history has been already given. There are, however, some additional facts connected with its early progress which deserve to be noticed, and which have been admirably stated in a lecture read before the Society of Arts, in 1852, by Mr. EDMUND POTTER, reporter to the Jury on Printed Fabrics in the Great Exhibition of 1851. Of these, as well as the important statistical details which his professional and official position afforded him peculiar means of obtaining, Mr. POTTER has kindly authorized the Editor to make free use; and therefore, for much of the substance of what follows with reference to the history and statistics of calico-printing, he begs to acknowledge his great obligations to that gentleman.

The art was first practised in Scotland in 1738, twenty-six years previous to its introduction into Lancashire. Garments only were printed there till 1754. The cloths were made in Scotland, and are spoken of as being made of linen yarns for warps, and cotton for wefts.

It was first established in Lancashire, in 1764, by the Messrs. CLAYTON of Bamber Bridge, near Preston. So anxious were the printers, a few years afterwards, to obviate the difficulty they then experienced in obtaining the cloth, that some of them actually left the more distant districts in which they were living, and even planted themselves where one of the main requisites for their trade—water, was afforded in a very limited supply. The cloth at this time was a calico made of linen warp, crossed with a cotton weft, and was called the Blackburn Grey. A circle of a few miles around Blackburn, long afterwards remained the great seat of the print trade, and that district has, even to the present time, retained a considerable portion of it. Another change in the mode of producing the cloth, tended, however, in no small degree to spread the trade over a wider district; namely, the introduction of the power-loom, which has now completely superseded—except it may be in the extremely low and light fabrics, to a very small extent—the hand-loom weaving, and which, in its infancy, the manufacturers of the Blackburn district dared not introduce, for fear of outrage by the workmen. It was brought into successful operation in Stockport and that neighborhood, and more particularly by the ASHTONS of Hyde, a name intimately associated by its talent, energy, and wealth, with the rising importance of the power-loom calico manufacturing trade, from the commencement of the present century. The best and largest quantity of power-loom printing cloth was first manufactured in Hyde, Stalybridge, and their immediate neighborhood, North Derbyshire. Print-works were afterwards erected in these localities, as they had been somewhat previously, on many of the streams in the immediate vicinity of Manchester.

To return to the period of the introduction of the print trade into Lancashire. The CLAYTONS were followed with greater vigor by Mr. ROBERT PEEL, the father of the first baronet, and grandfather of the late prime minister of this country. Mr. PEEL was a yeoman, and lived at Cross, near Blackburn. Active and energetic, he entered into the cotton manufacture, and added to it the printing business. It is stated by BAINES that he had it from one of his family, that the first experiments were secretly made in his own house, the cloth for printing—in those days by block only—being smoothed for the purpose by ironing. The pattern was one of nature's own—the parsley leaf. He carried on the business for some years afterwards at Brookside, near Blackburn, aided by his sons, and the concern was eminently prosperous. His eldest son, afterwards the first baronet, possessed strong talents, and devoted himself to business from an early age. This son branched off from his father's concern, and established himself at Bury, with his uncle, Mr. HAWORTH, and his future father-in-law, Mr. WILLIAM YATES, names now extinct in the trade, and only remembered as the sharers of the success of the PEEL family. PEEL was to calico-printing what ARKWRIGHT was to spinning: a man of iron mind and frame, possessing what seems to have been very rare among the early printers, great mercantile talent and application, amidst all the shocks of trade, which though then amazingly profitable, carried with it corresponding risks.

Mr. POTTER say he is acquainted with few records of taste of any kind amongst the Lancashire printers of those days. It was not so much needed, their energy and capital being the rather actively employed in branching widely out, and securing the best and newest modes of production. Of the rising men at the head of the various establishments, not a few received their early training from the PEELS, and had been selected by them to fill responsible situations, from which, in the natural course of events, they stepped, to be themselves the heads of future houses.

In 1771 and 1772 the Scottish trade more firmly established itself; and from that time seems to have adapted itself almost entirely to printing handkerchiefs and shawls for the English markets. Special notice is made of the supply wanted for Virginia, Maryland, and the West Indies. The trade of Glasgow, till within a comparatively recent period, was confined to shawls and handkerchiefs. It now produces other classes of work upon a par with those of Manchester, though much less in extent.

Calico-printing at one time was carried on so far north as Aberdeen, but the Editor has reason to believe it is now extinct there.

The production of Great Britain, which, in 1750, was supposed to be fifty thousand pieces per annum, had in 1796 risen to one million, and in 1830 to nearly eight million six hundred thousand—a progress of astounding rapidity, unequalled perhaps by anything but the history of the cotton trade itself.

The most important cause of this increase was doubtless the cylinder printing machine, which, like the steam engine of WATT, came almost perfect into use very early after its first erection in 1785. Some of the machines made shortly after that period were at work in the trade till within a few years past, and were capable of producing single colors with as much precision as any of the more modern ones.

Allusion has been made to the PEELS, as being—as far as Lancashire was concerned—almost the monopolists of the print trade of the last century. During the period 1796 to 1821, the FORTS, HARGREAVES, and THOMSONS, fairly established themselves as extensive and wealthy printers, not more by their energy and business talents, than by their scientific attainments, and by the unbounded and lavish support which they gave to everything which art and science could suggest to assist them.

To show the progress of the trade from 1796 to 1821, it may be sufficient to state that in the former year the quantity produced was one million pieces; in the latter, seven millions. Here it seemed to pause, and as a branch of the cotton trade, for the first time, to make little progress; this, too, with all the capital and energy of the numerous houses then embarked and well established in the trade. The solution of the difficulty soon made itself apparent, but was not so easy of removal. The trade was heavily taxed, and was the only one producing a textile fabric that was so. The cheaper other cotton fabrics of great variety were produced, the more onerous became the tax upon printed cottons. The most remarkable fact was, that the cheaper the printer obtained his cloth, the greater the per centage of taxation he paid. At first, when his material and produce were both high priced—the duty being threepence halfpenny the square yard—the tax amounted to perhaps 2½ per cent., but when it was repealed, and cloth had been cheapened, it had risen to probably 50 per cent. This acted as a bonus for the production of all other kinds of textile fabrics, in preference to printed cottons: nay, even printed silks were free, as were goods printed on the thread before weaving, producing the beautiful chéné effect, so freely used even now in silks, carpets, *et cetera*, and some descriptions of woven cotton goods. The duty had been regularly remitted on exported prints, and *that* portion of the trade shows a small increase in the ten years previous to 1831. For the five years preceding the repeal of the duty, there had been a positive decrease in the home consumption of prints, to the extent of nearly 15 per cent., —this, too, concurrently with an increasing demand for all other classes of textile fabrics.

The printers struggled hard for the removal of a tax in itself so unjust and impolitic, and which was evidently pressing very heavily upon their trade; but it was not till the spring of 1831 that they could obtain its removal. It was, however, one of the first beneficial remissions of taxation made by Earl GREY's government.

The removal of a duty, amounting on an average to 50 per cent. on goods produced for home consumption, naturally gave an immediate impulse, not merely by the reduction in the cost, but by the removal of the harassing and vexatious supervision, under which all trades suffering from excise duties must unavoidably be placed. Various statements were made at the time, as to the additional cost of production, which these restrictions entailed on the printer, and an experience of a quarter of a century has clearly proved that all the statements then made were even below the truth. Thus then the cost was lessened on 6,300,000 pieces exported, as well as on the 2,300,000 retained for home use. Great vitality was at once shown in the trade, and though the records of the excise are wanting since that period, and no public statistical accounts are kept, there is reason to believe that the trade which in 1830 produced 8,300,000 pieces per annum, now yields about twenty millions. Great changes in material, taste, and style, have necessarily been attendant upon so rapid an increase.

First, very great improvements have been made in the material printed on. The regularity of make, and evenness of fabric, in calicoes made by the power-loom, in all qualities, down to the cheapest possible production, gives the English printer a fabric for printing upon, which places him decidedly above the competition of the whole world, in this most essential part of his trade.

The increased demand for quantity led to great changes:—cheapness, the essential element, was attended to,—the machinery improved and quickened. The machines which had hitherto rarely placed on the cloth more than one or two, or perhaps three colors, were enlarged, and made to impress an additional number. Machines are now working producing fifteen or even twenty colors at once, with the same beautiful accuracy and precision as in the case of the smaller number; at the same time yielding six or seven hundred times as many pieces per day, as if blocked separately.

These changes, the perfection of machinery, the quickness of production, and its cheapness, have nearly superseded the slower process of block-printing, and this employment, like that of the hand-loom weaver, must decrease and disappear, except on finer fabrics of slight texture, on which machinery has not been brought to bear; chiefly, perhaps, from the small quantity not affording repayment for the outlay.

The changes in the trade during this period, led to the encouragement of a taste, not so showy as the chintz-block productions—for a long time the highest style in the trade—but of goods of a more elegant and quiet character.

It is but simple justice to acknowledge that at this date the English printer drew largely upon the style of his French competitors. The printers of the then called Swiss prints—really French goods produced in Alsace —were unrivalled in their pink and purple plate work. These goods, even for years afterwards, were imitated successfully, only by a few of the first-class English printers. The progress of the trade in scientific knowledge, now so patent to all, has enabled almost every printer in England and Scotland to produce, with more or less success, this class of goods, varying of course in excellence; in pinks, fully as good, when on an equal fabric, and in purples certainly surpassing those of Alsace. These goods, which were exported by the French, and met with in almost every capital city in the world, are now nearly superseded by the English plate, and to them has been added the supply of a new and increased variety of lower priced prints of a similar class. It is an interesting and curious fact, that the taste in almost every market has changed and improved with the introduction of these goods.

The English printer has also drawn largely upon his French competitor, during the same period, for another trade, which he has likewise, by the aid of the manufacturer and his machinery, done much to make his own. France has long been famous for her beautiful fabrics in fine wool, wool and silk challis, and de-laines, Expensive and costly, made of the finest wool, requiring the greatest care in execution, these goods have been produced with a taste in coloring and design worthy of the beauty and elegance of the material. With them France supplied and led the taste of all the civillized markets of the world. An article so costly was naturally limited in demand. The capital and machinery of the English printer have been brought to bear on this branch of the business. Cotton has been introduced into the fabric, and a beautiful substitute at a low price now occupies the place of the more costly all-wool material of our neighbours. The desired cheapness and beauty have been obtained. Block-printing on this material—the English wool and cotton-de-laine—was for some time the only mode of printing. Machinery has been adapted to it, and the English printer now introduces the cheap article at a low price in every known market, and creates a separate demand which the high-priced one would never have known. The cheaper article has introduced with it no corresponding reduction in quality of the design; quite the contrary; the wider demand for good taste, and the greater power of execution obtained by machinery, have led to new styles of great novelty.

The London printers, up to the repeal of the duty, still held their position for first-class goods. They made great use of the flat-press printing machine—cylinder printing having been but little used in the district. Indeed Mr. POTTER says, he was informed that the first cylinder machine was only introduced in 1812, twenty-seven years after its introduction in Lancashire. Their plates were well engraved, and for a long time they succeeded in getting a smartness of impression better than any at that time obtained from the cylinder. Some few of the Lancashire printers adopted the press, the better to compete with the London printer.

The rapidly increasing trade in Lancashire, and with it the power of so much cheaper production, gradually undermined the London printers, and brought about a complete change in their class of work. Their fine muslin trade for garments has been transferred to the Lancashire and Scotch printers. The London printer has availed himself of his greater advantages for block-work, and has applied himself to printing shawls, waistcoatings, and a variety of fancy handkerchiefs. Silk handkerchief printing has there its chief and almost entire seat for the supply of the whole world, and produces all the variety and excellence of pattern suited to its varied demand. London-printed shawls, the production of Mr. SWAISLAND of Crayford, were shown in the Exhibition; correct in taste, elaborate and beautiful in execution, and fairly equal to anything of the class produced in the French market.

It must be stated that the Lancashire printers, to a great extent, not only contended with the London printers in price, but availed themselves pretty freely of their taste. London patterns were produced at great cost, and their school of drawers was good. Their production being slow and careful, enabled the Lancashire printer by his machinery to fill the markets rapidly with his imitations and copies, to the very serious injury of the London printer. Better taste, and better morals, too, it is to be hoped, now prevail. The Printers' Copyright Bill, which at that period gave protection only for three months' duration, was in 1842 extended to nine months.

The London print trade is believed to be decreasing, and those who are best qualified to form an opinion on the subject think it will continue to do so. Peculiar branches of it will linger last, retained by the talent which often holds out for its generation, but is not renewed. The tendency of the trade is decidedly to concentrate itself; the market will not bear dividing. Thus the Scotch printers are found opening their establishments in Manchester, and transferring the larger part of their mercantile business there. And a new feature has just presented itself in the opening of an establishment there by a French print house of the highest standing.

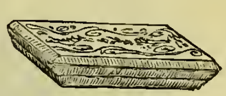
Having brought the history of the art of calico-printing down to the present period, for which the Editor repeats that he is almost entirely indebted to the valuable lecture of Mr. EDMUND POTTER, he reserves for the concluding part of the article the important statistics illustrative of its present condition in this and other countries, which are given by the same high authority, and which can perhaps be obtained from no other source.

PRINTING APPARATUS.—There are four methods of printing figures or designs on calicoes; the first is by small wooden blocks, on which the pattern is cut or otherwise produced in relief; the second by larger wooden blocks, also in relief, and placed in either two or three planes, standing at right angles to each other; the third by flat copper plates, engraved and applied as in ordinary copper-plate engraving, but now little used; and the fourth by a system of copper cylinders, engraved like the plates in intaglio, and mounted on a frame, in which they receive a rotatory movement by steam or water power.

Block-printing by hand.—Previously to the year 1785, hand-block printing, aided by the flat copper-plate printing press, was the only mode of calico-printing. It is impossible to assign the period when the use of the engraved wooden block first superseded the oriental method of literally painting the cloth; but the Greeks are known to have printed with blocks cut in relief before the taking of Constantinople. Though this method be now in great measure superseded by cylinder-printing, yet, as it is still continued for certain parts of the work, some account of the method of block-printing will be necessary.

The hand-block—Fig. 352—is made of sycamore, holly, or peartree wood, backed with deal, and furnished with a strong handle of box-wood. It varies in size from 9 to 10 inches long, and from 4 to 7 inches broad. About the year 1802, an important improvement was made in the construction of the blocks, for which the art is indebted to the workmen of London. Previously, the patterns were cut out in the wood, like ordinary woodcuts used in the prints of books, but the work was necessarily coarser, to endure the wear and tear of so many impressions, amounting, as formerly stated, to 448 applications of the block for each piece of cloth, and therefore requiring for 100 pieces not less than 44,800 impressions. If the design, therefore, was fine and elaborate, the block was soon worn away. The improvement effected removed this objection, and was very generally adopted. The pattern, instead of being cut in relief in the wood, was raised on the surface of a plain block, by pieces of flat copper or brass wire, of various thicknesses and forms, produced by drawing the wire through dies of different thicknesses and shapes These pieces of wire are forced into the wood by the taps of a hammer at the traced lines of the configuration; the upper surfaces are then filed flat, and polished into one horizontal plane, for the sake of equality of impression, presenting a surface which stands out from the wood about the eighth of an inch. The thicker parts of the pattern have merely the outline formed of copper, and are filled up with felt. As the slips are of equal thickness in their whole depth, the lines of the figure, however much they get worn by use, are always equally broad as at first, an advantage which does not belong to wood-cutting; and hence blocks on this construction are tenfold more durable than the old ones entirely of wood. Sometimes a delicate part of the design is made by the wood-cutter, and the rest by the insertion of copper slips.

Fig. 352.



Latterly, stereotyping has been applied to the production of printing blocks. To make the stereotype plate, a model is first formed from the pattern, about five or six inches in length, and from an inch and a half to five inches in width, according to the design. A mould is taken from the model, and from the mould, fixed in a block, copies are produced in the common stereotype metal—see ANTIMONY, page 205. When a number of these pieces are prepared, their surfaces are filed down, and they are then joined together, and mounted on a stout piece of wood to form a printing block.

The block-printing is performed in an oblong apartment, termed the printing shop, lighted with numerous windows at each side, and having a solid table opposite to each window. The engravings on next page—Figs. 353 and 354—exhibit the table with its accessories in plan and section. The table, T, is formed of a strong plank of hardwood, mahogany, or marble, with a surface planed quite true. It is about six feet in length, two in breadth, and three, four, or five inches thick. It stands on strong feet, with its surface about a yard from the floor. It is covered with either one or two blankets, carefully stretched, and fixed down at the corners. At one end of the table the legs, D, carry brackets for supporting the journals of the roller, A, from which the calico to be printed is unwound as the work proceeds, and passing along the table is carried successively over the hanging rollers, H, from which, as it descends, it is piled upon the stool, G. The rollers, H, are fixed as high as possible, sometimes in the apartment above, to facilitate the exposure and consequently the drying of the printed goods, and to prevent one figure being daubed by another.

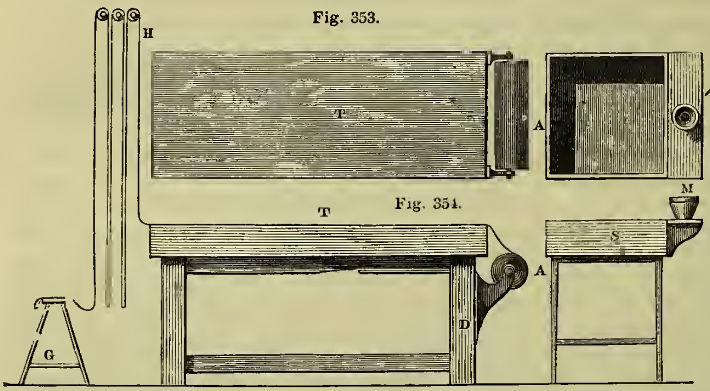
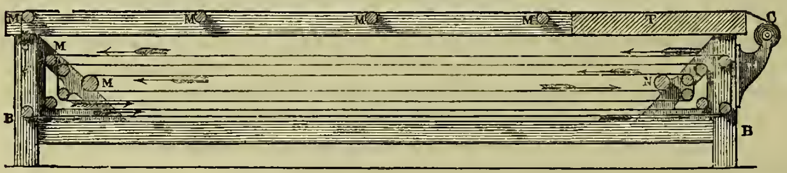


Fig. 353.

Fig. 354.

Sometimes, to avoid the necessity of passing the printed surface of the cloth over a roller immediately after leaving the table, the arrangement represented in Fig. 355 is adopted, where the stuff, passing from the roller, C, over the printing-table, T, continues its course over the rollers, M, M, M, M, from which it proceeds under the table round the rollers, B, B, and over the additional rollers, M, M, in constantly narrowing circumvolutions, as shown by the arrows, until it is finally wound upon the bobbin, N. By this arrangement the printed surface of the cloth does not come into contact with any of the rollers. The extreme bobbins, C, N, are fitted with winch handles to move the cloth forward, after printing a portion equal to the length of the table.

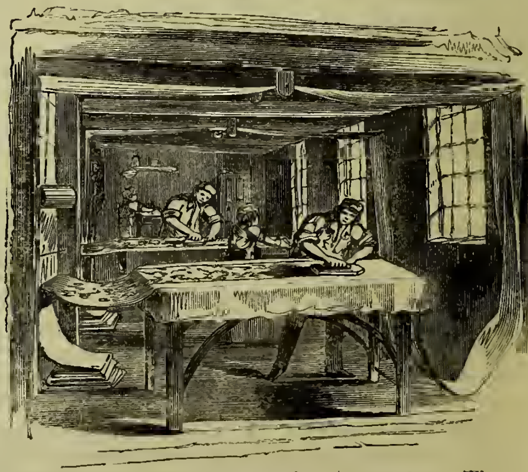
Fig. 355.



The workman charges the block with color by pressing it upon a surface of woollen cloth stretched tightly over a wooden drum, which is called the *sieve*, and is made to float in a tub of size or thick varnish, S—Fig. 354—for the purpose of giving it elasticity; M is the pot containing the supply of thickened color for the day's work. The inverted sieve or drum should fit the paste-tub pretty closely. The sieve is covered with the coloring matter by a child, called the *tearer*—probably from the French *tireur*—who takes up with the brush a small quantity of color from the pot, and spreads it uniformly over the surface of the sieve; and every time that the man presses his block upon the sieve in order to charge it with color, it is the duty of the tearer to brush over the woollen surface, in order to erase the mark of the block, that the latter may be evenly charged with color at the next operation.

It may here be stated that before proceeding to print the calico, it has to undergo the preparatory operations of singeing, bleaching, and calendering. The singeing is performed by drawing the cloth rapidly over a convex surface of sheet-iron raised to a red heat. By the rapidity of the motion, the cloth is not burned; but the loose down is effectually burned or singed off. By another method the cloth is drawn rapidly over an elongated gas flame. The processes of bleaching and calendering—see page 317—have been already described, and that of singeing will be more fully explained afterwards. Having passed through these operations, the cloth is ready for the printing; and a number of pieces, stitched end to end, are lapped round the roller at the end of the table. The printer unfolds a length of the piece upon this table, taking care to place the selvage toward himself, and one inch from the edge. He presents the block towards the end, to determine the width of its impression, and this width he marks along the piece on the table by drawing a line with his tracing point. The spreader or tearer now besmears the sieve with the color; the printer seizes the block with his right hand, and daubs it twice in different directions upon the sieve cloth; then he transfers it to the calico within the line marked, and generally strikes it on the back with a wooden mallet, in order to transfer the impression fully. Having done so, he again charges the block from the sieve; and to enable him to make the next impression exactly join or fit in with the last, the block is furnished with small pins at the corners, two of which he inserts in the marks that were made by the other two during the previous impression. Thus, by repeated applications of the block, a pattern is produced in one color. The accompanying engraving

Fig. 356.

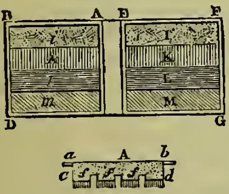


shows the block-printing process in operation, with the general character of the arrangements.

Printing different colors with one block.—If the pattern contain five or more colors, there must in general be as many blocks as there are colors, all of equal size, the raised portions in one, which take up color, corresponding with the depressed portions in the others, which do not. In order, therefore, to print a piece of cloth twenty-eight yards long and thirty inches broad, no less than 672 applications of a block, nine inches long and five inches broad, are requisite for each color; so that if there are only three colors, no less than 2016 applications will be necessary. But if the design consist of parallel stripes of different colors, they may be applied by one block at a single impression, and the block is also charged with the different colors by a single application to the sieve or surface of woollen cloth. The colors to be applied are contained in separate small tin troughs arranged in a line. A little of each color is transferred from the tin troughs to the sieve by a kind of wire brush, consisting of wires fixed in a narrow piece of wood, and the colors are distributed evenly in stripes over the surface of the sieve by a wooden roller or rubber covered with fine woollen cloth. In those patterns in which the colors merge into one another at the edges, constituting what is called the *rainbow style*, they are first blended by a brush on the sieve before being taken up by the block.

Considerable improvements have been effected upon this method, of printing simultaneously different colors with one block. The arrangement first adopted was that shown in Fig. 357, where E, F, G, H is a box or tray of tinned copper or iron, divided into a series of compartments for holding the different colors by partitions, I, K, L, M. A is a brush of equal length with the color-box, measured across the compartments, and divided into sections, *f f f*, with openings corresponding to the partitions, so as to constitute in fact a series of pencils. This brush the tearer dipped into the box to the depth of *c d*, and, in taking it out, pressed it against one of the sides to discharge the excess of color, and then moved it backward and forward on the sieve, A, B, D, C, depositing thereon belts of color, *i*, *k*, *l*, *m*, corresponding to the colors I, K, L, M in the box. To prevent him from pressing too much on the sieve, so as to produce a confusion of shades, the brush was made to rest on the sides of the sieve by projections, *a*, *b*.

Fig. 357.



But as this arrangement did not allow of depositing many tints on a limited space, since the different divisions of the brush required to be always at a certain distance from each other to prevent intermixture, the brush was laid aside, and the following method is generally practised at the present day:—

A—Fig. 358—is a box for holding the different colors, divided by partitions, C C, into as many compartments as are required. Till lately, these troughs were formed of tinned iron or copper, but latterly they have been constructed of wood or plaster, with slips of glass for the partitions. Fig. 359 is a piece of wood, on which are fixed, and drawn tight like the strings of a violin, copper-wires, *f f*, or hempen, cotton, or woollen cords. When formed of wire, the latter must be selected of a thickness corresponding to the quantity of color required to be deposited on any given point; it is then bent at right angles, and nailed to the sides of the piece of wood, as shown in the figure. When strings or cords are used, they are stretched between slips of copper, all of equal length, fastened to the sides of the board. Strings of different thicknesses may be selected, from a stout cord to a slender thread or filament, according to the breadth of the stripe of color to be laid on. Narrow ribands of copper, of different widths, have likewise been substituted for the wires or strings. The tearer applies the colors to the sieve by taking hold of the board, B, dipping the wires or strings into the compartments of the box, A, to which they are made to correspond in number, and then applying them to the sieve.

Fig. 358

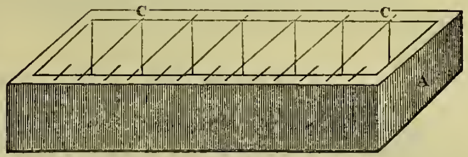
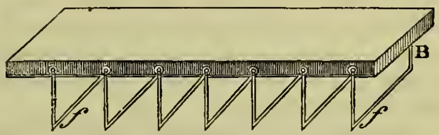
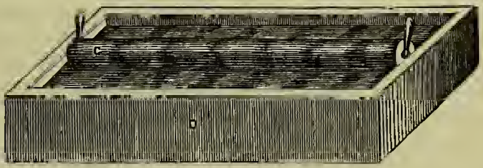


Fig. 359.



The lines or stripes of color thus deposited may then be spread by a brush; but a roller is better for this purpose, as shown in Fig. 360, where D is the trough containing the paste or mucilage on which the sieve rests, and G is a roller, fitting it exactly in length, and furnished with handles, by which the tearer moves it backward and forward lengthwise over the parallel stripes. The roller is thus prevented from deviating to either side; and when the colors are numerous, slits or grooves may be cut round it corresponding to the intervals between the colors or their points of junction, so as effectually to prevent their mixing together. By varying the thicknesses of the wires or strings, and by increasing them in number and contiguity to any extent, a great variety of striped patterns may be produced in this manner.

Fig. 360.



Further, the pattern may be made with curved lines of any form by a very simple arrangement, shown in the annexed cuts—Figs. 361 and 362. In this case the partitions of the box, A, are made of some flexible material, such as pasteboard, varnished over with any bituminous substance, and bent into any required shape; and the wires or metallic slips of the block, B, are made to correspond. When the colors deposited in this manner are spread with the brush, the effect is shown in Fig. 363, where D is the trough containing the sieve, and *f* the brush. It will be observed that the sides of the trough on which the ends of the brush rest are fashioned into corresponding curves, so as to communicate an oscillating movement to the brush as it passes over the tinctorial matters, and thus the same part of it always comes into contact with the same color.

Fig. 361.

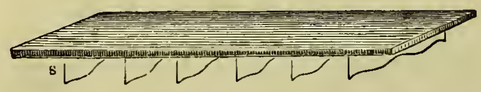
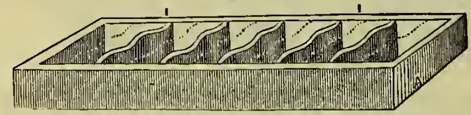
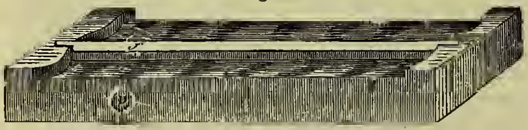


Fig. 362.



The principle of this method admits of numerous applications. Patterns of concentric circles or zones of different colors, and other varieties, may be formed by simply having the color troughs divided into corresponding compartments.

Fig. 363.



Improved Color-holders.—Mechanical details do not properly fall within the province of this work; but in the various processes of calico-printing more mechanical ingenuity is displayed than probably in any other chemical art; and no adequate idea can be formed of its wondrous resources and applications without an intelligent appreciation of the apparatus employed. An article or treatise on the art would indeed be very incomplete and unsatisfactory which did not to some extent enlighten the reader on this subject; and this the Editor is the more disposed to attempt, as he is not aware that there are any works in the English language in which the apparatus used in calico-printing has received justice, either in point of description or illustration.

The truth of these remarks will appear when the methods of cylinder-printing, and block-printing by machinery, are discussed. In the meantime, the Editor will proceed to describe, as briefly as possible, some improvements in the apparatus connected with block-printing by hand.

In the first place, there are some colors—such as certain blues—which cannot be long exposed to the oxygen of the air without injury. To avoid this, the very simple arrangement represented in Fig. 364 has been adopted. A is a small copper vessel, two or three inches in depth, and a little longer in horizontal dimensions than the printing-block. This vessel communicates at its lower part with the color cistern, B, by a tube fitted with a stop-cock, R; and at about half its height is fixed the woollen sieve, T. When the stop-cock is opened, the color from the cistern arrives under the sieve, and tends to press upward through it, with a force proportioned to the height of the column of color in the vessel, B; and the quantity of color which forces itself through the sieve may be nicely regulated by the stop-cock.

It is evident that this arrangement may be adopted with troughs divided into compartments for containing different colors. In that case, each compartment is made to communicate by a tube with its own cistern, as represented in Figs. 365 and 366, the former of which is a plan, and the second a vertical section of the color-troughs and tubes. Suppose, for example, that the pattern to be printed consists of four colors—green, red, yellow, and violet—in that case there are four cisterns or reservoirs, A A A A, forming the sides of the sieve, which is divided into compartments, E E E, according to the shape of the pattern. The cisterns, A, communicate by tubes, B, of lead, caoutchouc, or gutta percha, with the lower surface of the sieves, E, which are separated from each other by leaden or wooden partitions, to prevent the colors from mixing. It is almost needless to state, that the colors must have sufficient fluidity to flow freely through the tubes, as well as to penetrate the meshes or pores of the sieves; and they ought to stand in the cisterns, A, at nearly the same level as the sieves, so that a constant supply may be maintained, sufficient to penetrate the latter without forcing their way in superabundant quantity.

Fig. 364.

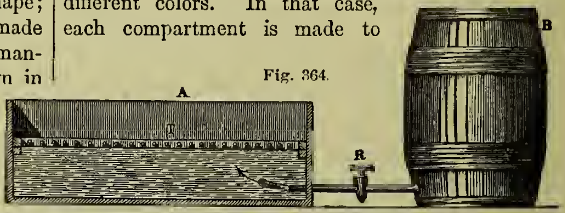


Fig. 365.

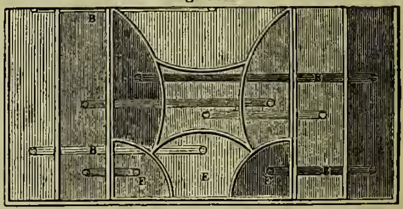
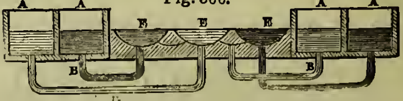
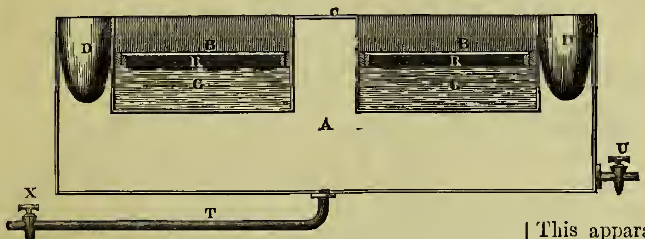


Fig. 366.



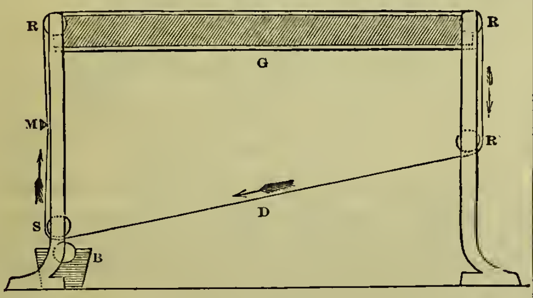
Some colors or mordants require a higher temperature than that of the printing shop to bring them to a state in which they can be best applied to the cloth. In that case, the sieve-trough, with its cistern, may be inserted in a larger vessel filled with water kept at a certain temperature, or heated by steam. An arrangement of this kind is shown in Fig. 367, where B G, B G, are two copper vessels corresponding to A in Fig. 364, each fitted with its sieve, R, for the use of a couple of printing tables. D D are two small basins for holding the color, and which, as well as the sieve-tubs, G G, dip into the steam-chest, A. The tubes, T X, and U, are for admitting and discharging the steam.

Fig. 367.



Mechanical Tearers.—Different arrangements have been invented to dispense with the services of boys for spreading the colors. By one method, the tub or trough containing the mucilaginous cushion, or *false color* as it is called, instead of being covered with a fixed sieve exactly fitted into the trough, is covered, on the contrary, with an endless web, which circulates from the color-pot placed beneath it, as shown in the annexed engraving—Fig. 368—where G is the tinned trough or tray, filled with the paste or false color, and covered hermetically by a waxed cloth, so as to be slightly convex on the surface. Over this surface, and receiving its movement from the cylinder, S, circulates the endless web, D, passing round several rollers, R R R, and charged with color on one of its surfaces by the roller, B, which circulates in the trough containing the color. The superfluous color is thrown back into the trough by the scraper, or *doctor*, M. The printer applies his block to its upper surface over the paste cushion, G.

Fig. 368.



This mechanical tearer, as such contrivances are termed, has several disadvantages. Besides being somewhat expensive in the first construction, and requiring a constant power to keep it in motion, it is not fitted for the transmission of those colors which speedily dry or thicken when exposed to the air.

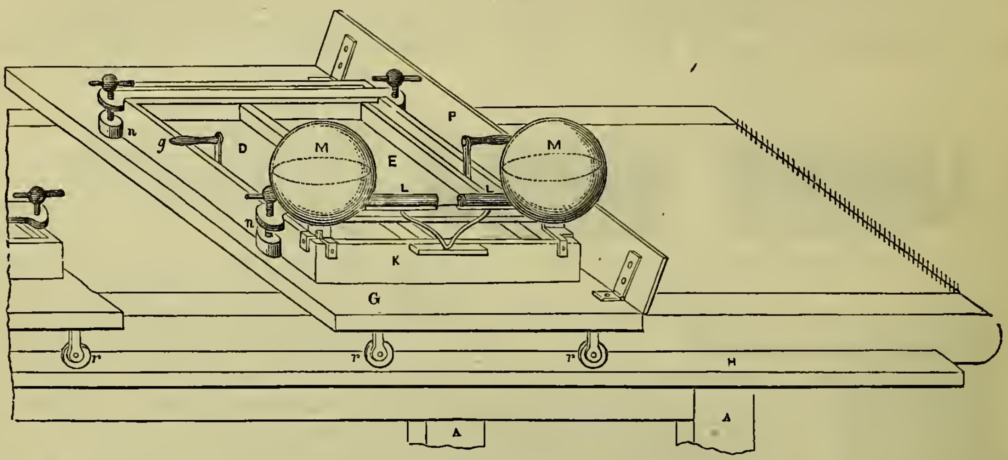
A mechanical tearer, which is not liable to these objections, was invented by M. M. DUPASQUIER of Neuchâtel. It consists of a trough for containing the color, over which the sieve is extended, so that the color itself acts as the mucilaginous cushion. A cross bar, mounted on small wheels, running on rails, which are fixed upon each side of the trough, carries two elastic plates or blades, which press with their edges on the sieve and spread the color. This part of the apparatus is properly the mechanical tearer; and, by a very simple system of pulleys, is connected with a pedal attached to the printing-table; so that the printer, by merely pressing with his foot on the pedal, draws the spreaders over the sieve, and again, on removing the pressure, these are immediately carried back by a counterweight. This apparatus is highly recommended by PERSOZ; but it has also its disadvantages; and, indeed, the attendance of a boy is often useful to the printer to assist him in spreading his cloth and for other purposes.

Movable Color-holders.—Sometimes the printing-tables require to be of great length—from twelve to fifteen yards—to receive, for example, costly fabrics for dresses, which are to be printed and finished in one piece, and to which it is desirable that all the colors composing the design be applied in succession, without changing the position of the cloth during the process. In such cases one can readily conceive the inconvenience of having the color-trough stationary at one end of the long table, not only causing loss of time in passing backwards and forwards to charge the block after each impression, but rendering the colors liable to dry or thicken upon the block before they are applied to the stuff.

To obviate these disadvantages, the whole apparatus connected with the color-trough is sometimes made to run upon rails, fixed upon the sides either of the printing-table itself, or of another table placed parallel to it. The best arrangement of the kind is that recently invented by M. PAUL GODEFROY, and shown in the engravings—Figs. 369, 370, and 371—both in its *ensemble* and in detail. In each of these figures the same letters refer to the same parts.

A A are the feet or supports of a table, similar in construction to the printing-table already described. This table may have any required length, and is furnished on both sides with grooves or rails, H, on which run the castors, *r r*, of the movable stands, G. This last supports the color trough, K, which, yielding to the slightest impulse, advances or recedes at the will of the printer; or, if the style of printing require it, it is moved backwards and forwards by the tearer, who stands on a platform parallel with the table. K is a wooden box, with its joinings accurately fitted together, and having on each of two opposite sides two notches or indentations, *k k*, to receive the cross-pieces, *a a*, fixed to a frame or chase, C. This box, K, may be divided into any number of compartments, by partitions, *f*, as shown in Fig. 371; and the color introduced into this box performs at the same time the part of the paste cushion, the sieve being placed immediately over it to be impregnated with the color. The latter is admitted into the trough or withdrawn from it by the openings, S, S. D, E are simple chases, or sieves, formed of a square wooden frame, with woollen or other stuff stretched over, capable of permitting the color to pass through when a certain pressure is applied. At the two ends of this frame are fixed the cross-bars, *a a*, which, by falling into the notches, *k k*, keep the frame in a fixed position. These cross-bars carry at their extremities wooden screws, *m m*, which turn in wooden nuts, *n*, *n*, fixed to the color-trough; and by means of these screws the printer can elevate or depress the sieve in the color as he finds necessary. The chases, D, E, with compartments, are shown upside down, to exhibit the groove or grooves corresponding to the partition or partitions, *f*, of the trough, K.

Fig. 369



To keep the color at a constant level, when the screw has been adjusted in its proper position, matrasses, or globular glass vessels, M M, are fixed at the corners of the side of the trough opposite to that at which the printer works. These matrasses are filled with color and turned upside down in the trough, so that when the color contained in the latter sinks a little, a portion of air rises into the globe, displacing an equal portion of color. These matrasses, therefore, act as color cisterns.

Fig. 370.

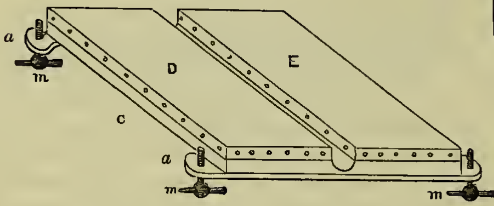
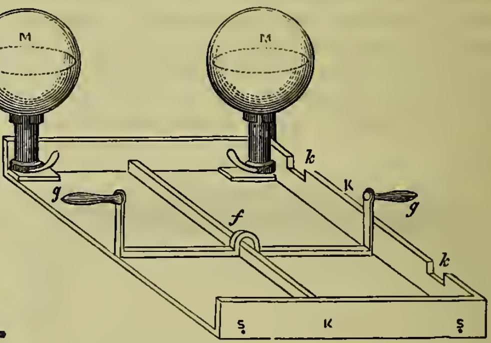


Fig. 371.



As the color requires to be occasionally stirred, each trough is fitted with a bent rod, which is moved by turning the handles, *g*, and thus affords the means of thoroughly mixing the color without raising the sieve-frame. Further, to equalize the color on the surface of the latter, a small roller, L, which may be either single or compound, according to the number of compartments, is passed from time to time over the surface.

Lastly, to the stand, G, is fixed a board, P, in an oblique position, to defend the calico or other fabric in the course of being printed, from drops of color which are apt to fall from the block while the printer is raising it from the sieve.

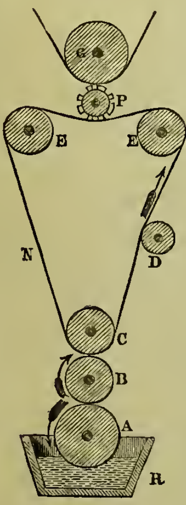
This arrangement may be used for printing a number of colors with the same block, in the manner already described for the rainbow style. It adapts itself to any length or size of table. It seems to be applicable, in short, to any kind of block-printing.

BLOCK-PRINTING BY MACHINERY.—Employing the expression *block-printing* in a somewhat lax sense to signify generally printing by surfaces in relief, the Editor will now consider the methods devised for bringing the precision and rapid execution of mechanical power to bear upon this department of calico-printing. It is true that if the order of time was followed, the method of printing by engraved cylinders of copper, having the design cut into the surface, would now fall to be considered; for this was the mode which first superseded the hand-block in common practice—which first introduced, in short, the general application of mechanical power, as a substitute for manual labor and dexterity in calico-printing. From its vast importance, however, and its almost universal application, cylinder-printing is reserved as the last and principal subject for illustration; while, at the same time, it is only natural to follow up into its latest improvements that method of printing by surfaces engraved in relief, of which the common hand-block is the type.

Surface-Printing.—When cylinder-printing was introduced with so much success, and even before its introduction, it was natural to think of applying the same continuous system to surfaces engraved in relief —to form, in fact, cylindrical blocks, with the figure or pattern standing out from the surface as in the common block, and to obtain from these a continuous series of impressions by mechanical agency. PERSOZ states, that the first machines of this kind appear to have been invented in France, and were termed *plombines.* A person named EBINGER, of St. Denis, near Paris, took a patent for the invention in 1800, hoping to imitate the English printers, who, for several years prior to that period, had worked by a continuous mechanical method, the processes of which were then unknown in France. This mode of printing, which was formerly practised extensively in some establishments, is called *surface-printing*, probably, says URE, because the thickened color is applied to a tense surface of woollen cloth, from which the roller takes it up by revolving in contact with the cloth. The union of a wooden cylinder in relief with an engraved copper cylinder, forms what has been denominated the *union* or *mule machine*, and was the invention of Mr. JAMES BURTON, about the year 1805, when he was an engineer in the establishment of Messrs. PEEL and COMPANY, of Church.

Fig. 372 exhibits the most improved arrangement for the application of the wooden cylinder in relief. The endless web, N, receives the color from the trough, R, by the rollers, A, B, which, by their friction against each other, tend to spread it uniformly, and this is still further accomplished by the roller, D. The endless web was formerly made to pass over only two cylinders, one in the position of C, and the other immediately under the printing cylinder, P. By that arrangement, however, it was found that the cylinder, P, did not sufficiently take on the color, the surface of the cylinder below being also convex. Hence the improvement effected by circulating the woollen cloth, in the upper part of its course, over two cylinders, E, E, placed at the same height; and this cloth, being tightly stretched, yields a kind of bed or cushion for the relief surface of the cylinder, P. The calico to be printed circulates round the roller, G.

Fig. 372.

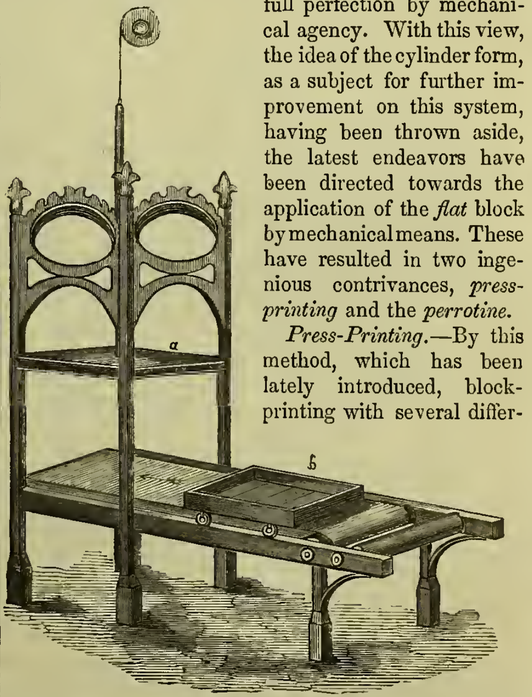


The design may be formed on the cylinder, either in the manner of ordinary blocks for woodcuts, or by inserting slips of copper. This method of printing has one important advantage over the engraved copper cylinder, when two or more different colors are to be applied to the cloth. In this case the portion of the pattern impressed by one copper cylinder is always subjected to the action of the unengraved portion of the other cylinders, which to a certain extent must render it less clear and distinct by spreading it a little upon the stuff, whereas, when the second color is printed with a cylinder in relief, the color that was first printed is left untouched. Hence the advantage of combining the block system with the copper cylinder, as in the union machine. The block, or cylinders constructed on the principle of the block, have also this advantage, that they do not come into contact with the ground of the fabric, which, whether it be a pure white, or any delicate color, must always be more or less stained by the unengraved surface of the copper cylinder, whatever precautions may be taken to remove the superfluous color. Hence, surface printing is still employed with advantage in the union machine, and is more especially useful for producing impressions of white and yellow patterns on blue grounds.

There is, however, one fatal defect connected with this cylindrical block system, which it has hitherto been found impossible to remedy—the color impressed in this way by a curved surface is always more or less spread out, not being kept to the same precise spot as in the lines or hollows of the engraved cylinder; and hence the beauty and regularity of the forms composing the pattern are always more or less impaired.

Still, the important advantages of the block, in coming into contact only with those parts of the cloth intended to receive the color from itself, and neither with the white or colored ground, nor with the other parts of the pattern already printed, have naturally induced a variety of efforts to work it in full perfection by mechanical agency. With this view, the idea of the cylinder form, as a subject for further improvement on this system, having been thrown aside, the latest endeavors have been directed towards the application of the *flat* block by mechanical means. These have resulted in two ingenious contrivances, *press-printing* and the *perrotine.*

Fig. 373.



Press-Printing.—By this method, which has been lately introduced, block-printing with several different colors may be executed to some extent mechanically at one impression. A sketch of the principal parts of the machine employed for this purpose is shown in Fig. 373, and its mode of operation is very well described by **Parnell** in the following terms:—The block itself, *a*, consists of a well prepared tablet of wood, about two feet six inches square, supported in an iron frame in such a manner that it can be raised or lowered vertically at pleasure. The face of the block is divided into as many stripes—crossways with the table—as there are colors to be printed, which may be supposed, for illustration, to be five. The stripes are about six inches in breadth and as long as the breadth of the cloth to be printed; each one prints a different color, and the whole five form together the combined pattern. The printing surfaces are stereotype casts, made of the mixed metal, antimony, tin, and lead.

The mode of applying the colors to the printing surface is very ingenious. At the bottom of the wooden frame, *b*, near to one end of the table, is a felt cushion about the same size as the entire block, and immediately within one side of the frame are arranged in a line five little troughs—or as many as there are colors to be printed—containing the thickened colors. By means of a long piece of wood, so formed as to dip into all the troughs at once, the attendant tearer applies a little of each of the five colors to the surface of felt, over which the colors are evenly spread by a brush in five stripes without any intermixture. The breadth of the stripes is the same as the breadth of the stereotype rows on the block.

The cushion being thus charged, the frame is slid forward on the table on a kind of railway, until it lies immediately underneath the block, which is then lowered by the pressman upon the felt cushion, whereby each of the five stripes on the block becomes charged with its proper color. This being done, the block is raised, the color-frame withdrawn, and the block caused to descend on the cloth, which it imprints in five rows with different colors. When the block is raised, the cloth is drawn lengthways over the table about six inches, or exactly the width of one stripe on the block: the tearer again slides over the cushion with more color, and the block is again charged and applied to the cloth. As a length of the cloth equal to the width of a stripe is drawn from underneath the block at each impression, every part of the cloth is brought into contact successively with all the stripes on the block. The part printed by the fifth stripe at the first impression becomes printed by the fourth stripe at the second impression, by the third stripe at the third impression, by the second stripe at the fourth impression, and by the first stripe at the fifth impression. When this machine is well managed, its action is very neat; but extreme nicety is required in properly adjusting all the moving parts of the press in order to prevent confusion of the colors and distortion of the pattern.

The Perrotine.—This machine, which is so called in honor of its inventor, M. **Perrot** of Rouen, is characterized by **Persoz**, without even excepting the steam-engine, as perhaps the most interesting invention of mechanical genius. It was introduced into the French printing establishments in 1834, but has subsequently undergone very considerable improvements. Fig. 374 represents an elevation, and Fig. 375 a vertical section of the perrotine.

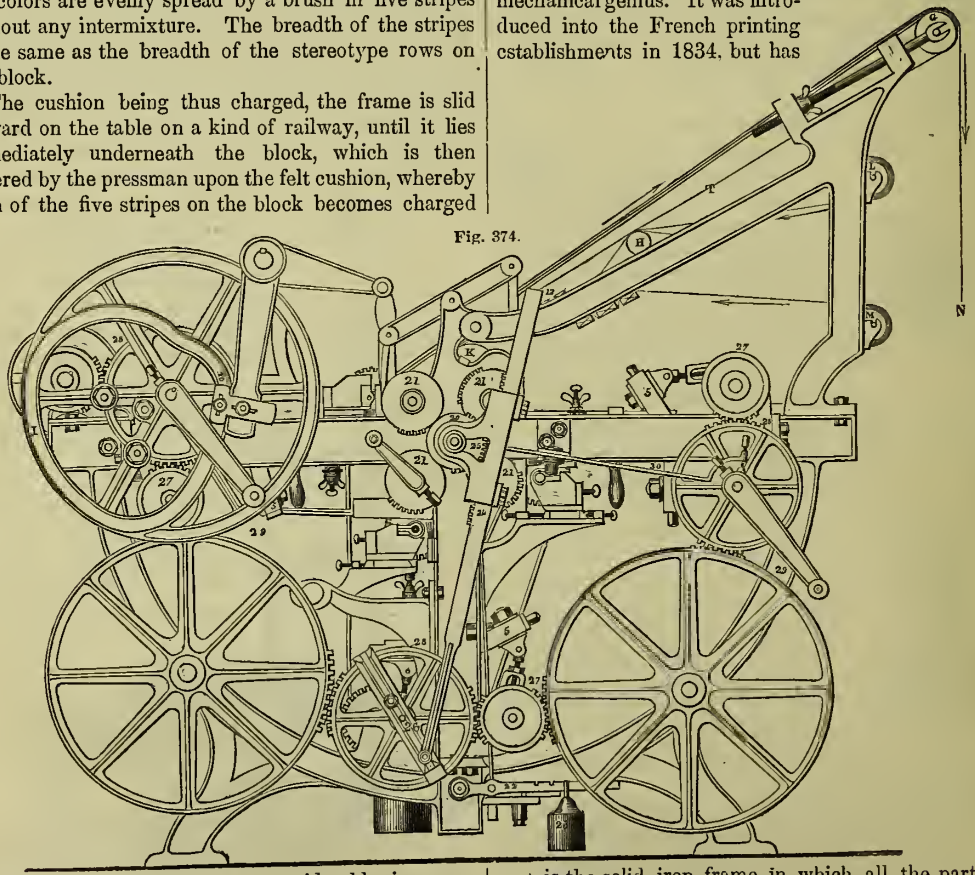
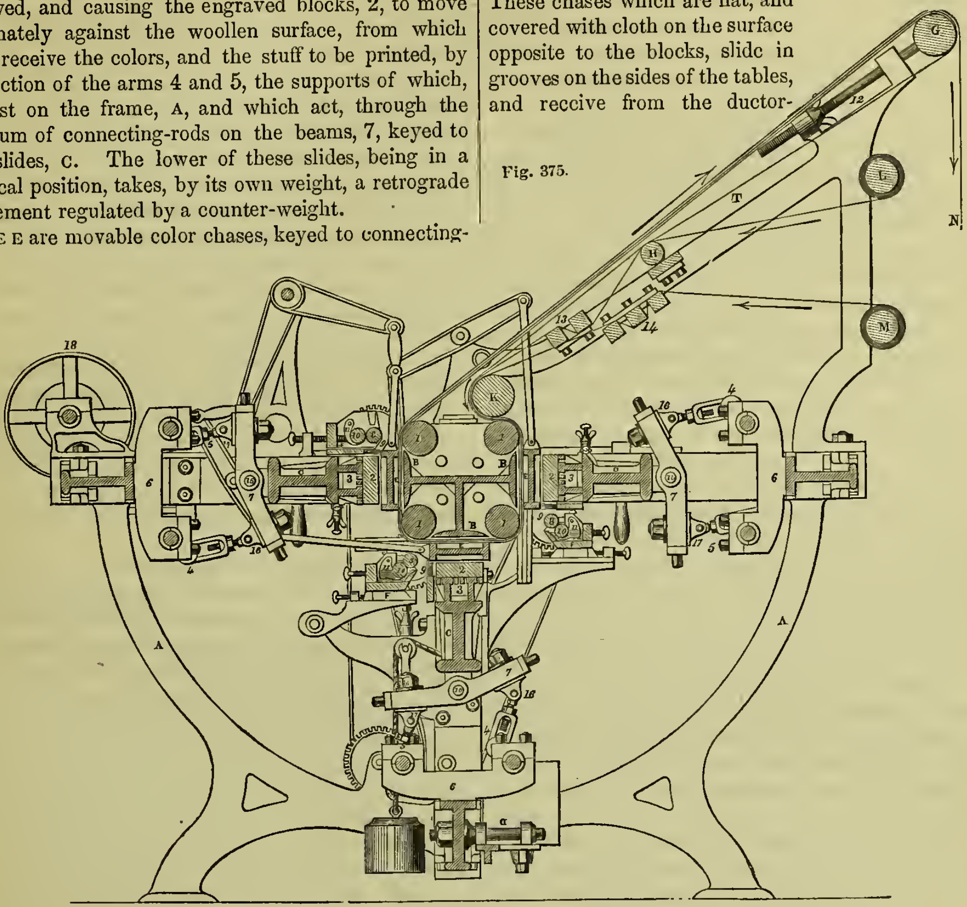


Fig. 374.

A is the solid iron frame in which all the parts of the machine are fixed. **B B B**, iron tables, dressed perfectly smooth, on which circulate the endless web, the blanket or *doubler*, and lastly, the fabric to be printed; C C C, sliding pieces, to which the block-holders, 3, are screwed, and causing the engraved blocks, 2, to move alternately against the woollen surface, from which they receive the colors, and the stuff to be printed, by the action of the arms 4 and 5, the supports of which, 6, rest on the frame, A, and which act, through the medium of connecting-rods on the beams, 7, keyed to the slides, C. The lower of these slides, being in a vertical position, takes, by its own weight, a retrograde movement regulated by a counter-weight.

E E E are movable color chases, keyed to connecting-rods, and receiving from the power applied to the machine the kind of movement which they require. These chases which are flat, and covered with cloth on the surface opposite to the blocks, slide in grooves on the sides of the tables, and receive from the ductor-rollers the colors which they afterwards transmit to the blocks.

Fig. 375.



F F F are the color troughs, filled with color, and furnished each with two rollers, 8 and 10, the last of which, dipping into the troughs, are charged with color, which they communicate to the rollers, 8, the latter being covered with woollen cloth, and these in their turn transmit their color to the chases, E, on which it is spread by the fixed brushes, 9. As it is important to be able to vary at pleasure the quantity of color supplied to the chases, and consequently to the blocks, the rollers, 10, are in connection with levers, 11, which, by means of adjusting screws, bring them into more or less intimate contact with the rollers, 8, and consequently vary the charge of color at pleasure.

The mechanism for circulating the endless web, the blanket, and the fabric, is as follows:—At the four angles formed by the three tables, B, are rollers, 1, armed on their surface with needle-points, which prevent the cloths from slipping as they pass round, and thus secure the regular movement of the stuff to be printed, a movement determined by the toothed wheels, 21—Fig. 374—fixed at the extremities of the axes of these rollers. G is a roller for stretching the endless web, resting with the two ends of its axes on two cushions forming the extremities of the screws, 12, by which the roller can be pushed further out when required to give the cloth the necessary tension. H is another tension roller, supporting the endless web and the blanket. K is a roller which serves similar purposes for the endless web, the blanket, and the fabric in process of being printed. T, the endless web, which in its course embraces the semi-circumference of the roller, G, passes over the roller, H, and behind K, to circulate round the cylinders, 1, and over the surfaces of the tables, B.

L is a cylinder from which the blanket is unwound, being first stretched by the roller, H, and then drawn out in its breadth by the widening rules, 13, from which it proceeds to join the endless web on arriving at the roller, K. M, a winch from which the calico or other stuff to be printed is unrolled by the movement of the machine passing through the widening rules, 14, to join at K the endless web and the blanket, which it accompanies in their course till it arrives at the roller, G, where it passes off to the hanging rollers in the direction of the line, N.

It now remains to explain the action of the machine.

It is worked either by the hand with a winch-handle, or by power communicated by a strap which passes over the pulley on the left hand, marked 18. This pulley has several diameters to give different speeds; it is loose on the driving shaft, and carries catches by which it communicates its motion to the mechanism when the machine is to be worked.

Directing attention, in the first place, to the movement of the cloth, it will be seen that this movement, like the printing itself, is necessarily intermittent. It must also advance at each step by a distance exactly equal to the breadth of the block, and this advance must be executed during the time that the chases are being charged with color from the ductor-rollers, 8. This result is obtained by means of a dividing-wheel, 20 —Fig. 374—connected with corresponding mechanism. The wheels, 21, fixed at the extremities of the axes of the cylinders, 1, and having each the same number of teeth, receive their movement from a central wheel, toothed in the same manner, and placed behind the wheel, 20. This last receives an alternating motion from a rack, 24, fixed in a copper piece, 25, and which rises and falls alternately, being keyed at its lower end to one of the spokes of the wheel, 28. By varying the position of the point at which the end of the rack is connected with the spoke, 26, the length or range of its movement is proportionally changed, and more or less of the teeth of the wheel, 20, are made to pass, which renders proportionally greater or less the advance of the cloth at each movement; and this is further regulated by a ratch-wheel placed at D. At each half-turn of this last, the lever, 22, raises the catch or pallet, and throws out of gear the wheels, 21, during the other half-turn; but as in the working of these wheels, there would inevitably be a backward movement, this is prevented by a break consisting of a pulley mounted on the shaft of the axis of the wheel, 20, and a brass wire, which, after making a turn and a half or two turns on this shaft, is stretched by the weight, 23, which offers a sufficient resistance to any recoil.

The next point to be considered is the action of the slides or block-holders. These are put in motion by the wheels, 27, 28, gearing with the larger wheels, 29. And to vary their action at pleasure, both for causing the blocks to bear more or less strongly on the chases, so as to be more or less charged with color, and likewise for attaining the exact pressure which suits best for the color to be laid on, it is sufficient to move the points of junction, 16 and 17, to a greater or less distance from the point marked 15, which constitutes the centre of oscillation of the beams that work the slides.

The movement of the chases is controlled by that of the cam, I I 30, which works them all three by putting in motion a shaft with which they are respectively keyed.

The ductor-rollers receive their movement from gearing with pinions on the axes of the rollers, 8.

The Editor will now endeavor to explain the general working of this complex machine. When put into regular motion, and the three blocks have delivered their impression exactly at the same instant, three simultaneous movements immediately commence.

1st. The stuff advances by a length exactly equal to the breadth of the block, and with it the endless web and the blanket, so that the portion of the fabric which leaves the third block behind it is fully printed; that which was under the second advances opposite the third; that which was under the first moves along to the second; and a fresh breadth of the white or unprinted fabric arrives opposite the first.

2d. While the cloth is advancing as above stated, the chases take the place which they occupy in the section—Fig. 375—that is to say, the first, on the right hand, rises, the second moves from left to right, the third descends; and in this movement all three press slightly on the ductor-rollers, 8, from which they receive the color, which has been spread uniformly by the brushes, 9.

3d. In the meantime the slides or block-holders, by a forward movement, push the blocks against the chases, to charge them with color, and the blocks at the same time receive from the slides a gentle backward movement, during which the chases deviate from their position; the blocks then return upon them and are drawn back again, after being applied to a new part of the color surface.

When these simultaneous movements have taken place, the action of the machine proceeding without intermission, the chases move back from before the blocks, and these are pushed up against the latter, printing the portion of the fabric which is stretched upon them. This brings the machine to that portion at which the description commenced; and this succession of movements is renewed and repeated as long as the operation lasts, the attendant having it always in his power to suspend the advance of the stuff whilst the working of the blocks and chases continues, so that the color may always be re-applied to the same part of the fabric as often as may be required for a good impression.

In 1844 M. Perrot exhibited a machine for printing four colors, the same in principle as that which has just been explained, but somewhat more difficult of construction. In the perrotine, as now improved, says Persoz, the printer finds, along with a much more correct execution of difficult patterns, a great economy of manual labour. Variously-colored patterns are printed by it on pure white grounds with the utmost delicacy of execution; and, as regards saving of labor, two men print in three colors with the perrotine from one thousand to fifteen hundred yards of calico daily—an amount of work which, with the ordinary block, would require twenty-five printers and as many tearers. It may be added that by suitable arrangements, and by employing tearers to distribute the colors in the chases, the perrotine has also been successfully employed in producing the rainbow style. M. Perrot has even contrived a method of working by the machine in this style without the assistance of tearers.

Copper-plate Printing.—To produce more delicate patterns than could be engraved on wood, at the period when printing by the hand-block was the only method employed, copper-plates were introduced in the neighborhood of London about the year 1770, and the cloth was printed from these flat plates with the kind of press used for printing engravings on paper. This method of printing has long been almost entirely superseded by the copper cylinder, which may be regarded as in principle nothing but a simple plate bent into a circular form, and therefore it is quite unnecessary to enlarge upon the flat plate system at any length.

The difference between this system, whether in the form of a plate or a cylinder, and that of the block, whether applied by the hand or by the perrotine, consists in the fact that the design or pattern, instead of standing out from the general surface, is cut, sunk, or impressed upon it in *intaglio*, so as to be lower than the surface. In printing, therefore, with the plate or cylinder, the whole of the engraved surface is first covered with the color, and then means are employed to remove this from the smooth part of the surface, leaving it in the hollow or sunk parts of which the pattern consists; and by applying sufficient pressure the surface of the stuff to be printed is forced into these hollows, from which it extracts the color and receives the impress of the pattern.

CYLINDER PRINTING.—The introduction of the copper cylinder, engraved in the manner of the flat plates, by which it was evidently suggested, formed, as already remarked, by far the most important improvement ever effected in the art of calico-printing. It has also been stated—page 568—that this invention is claimed to have been first made by a calico-printer named OBERKAMPF, at Jouy, in France, but was afterwards independently discovered by a Scotchman of the name of BELL, and was first successfully applied in Lancashire about the year 1785, by the house of LIVESEY, HARGREAVES, and Company. The latter part of this statement is quite correct; but OBERKAMPF'S claim to be the first inventor of the cylinder, although it will be found acknowledged in all the works on calico-printing, is really without foundation. Indeed it must appear remarkable and unaccountable, even on a *primâ facie* view of the case, that if so important a discovery was first made in France, at any time prior to the year 1785, its successful application should not have been achieved in that country till many years after it was firmly established in England—not indeed till the beginning of the present century. The simple truth of the matter is, as now clearly established on incontestable evidence, and admitted by M. PERSOZ himself, that OBERKAMPF imported the engraved cylinder from England, and first introduced it at his establishment at Jouy in 1800. M. DOLLFUS GONTARD, an eminent French printer, in a letter addressed by him to M. HUGUENIN CORNETZ of Mulhouse, distinctly states that OBERKAMPF was the first person in France who used the engraved cylinder, and that he was indebted for all the details of the invention, and all the machinery connected with it, to an English mechanic, who remained fifteen or eighteen years attached to his establishment. The name of this English mechanic is given by the writer of the letter in question as M. HANDRÉS, probably a French corruption for ANDREWS, or some similar name. M. GONTARD affirms that OBERKAMPF'S first productions in this kind of printing appeared in 1800, and adds that in 1801, and the five following years, the demand for these productions, though limited to one color, and the simple mignonette pattern, was immense. EBINGRE, another calico-printer, who had been formerly a workman in OBERKAMPF'S establishment, discovered the secrets of the new process through some of his old associates still employed there, and, in conjunction with a person of great mechanical genius named LEFÈVRE, erected in his own establishment machines on the same principle, which afterwards came into pretty general use.

Such was the history of the introduction of cylinder-printing into France, from which it appears that OBERKAMPF has no claim whatever to the invention; and this is even admitted by the very terms in which his title to it is asserted by the French writers; for all agree in dating it no further back than the beginning of the present century, when cylinder-printing had already been successfully carried on in England for a period of at least fifteen years. For example, in a French work, entitled *Elementary Lessons in Chemistry*, which was published at Rouen in 1839, it is stated that prior to the year 1801, the calico-printers had only two methods of printing, the hand-block and the flat plate; but at this period the celebrated OBERKAMPF, of Jouy, attempted in his fine printing establishment, so long without a rival, to print with engraved copper cylinders. This new method, continues the French writer, which the Manchester printers were not long in adopting and improving, so as to render it at once simple and expeditious, produced a revolution in the art, the effects of which were incalculable. This account of the case is simply amusing, and would indeed have been scarcely worth refuting, had it not been taken up and repeated, so far as regards the ascription of the first invention of the system to OBERKAMPF, even by English writers, who knew and stated at the same time that the method was practised in England with complete success so early as in 1785.

With regard to the actual invention of the system, this must be referred to a date still earlier. POPE, in his *Manual of Discoveries*, states that, in 1770, Messrs. CHARLES TAYLER and THOMAS WALKER, of Manchester, printed fabrics with wooden cylinders, on which the designs were engraved in intaglio. PERSOZ considers it more than probable that these cylinders were formed, not of wood, but of copper plates bent round, and soldered at the edges. On the other hand, it may be doubted whether they were not constructed of wood, but cut in relief like the common block, which seems to be the method that would have most naturally suggested itself in connection with the idea of a cylinder at that period. At the same time, it is quite possible that this may have been, as PERSOZ conceives, the first attempt to apply the invention of BELL, and that, having proved a failure in the first instance, from certain defects of construction, it was only applied with success in 1785.

The Editor has been thus minute and particular in stating these facts, because it has been usual to ascribe to OBERKAMPF the principal merit of this important invention; a merit to which it appears, even on the authority of French writers themselves, that he has not the shadow of a claim, even as a second and independent discoverer. Cylinder-printing is purely a British invention, and the entire and undivided honor of the discovery must be given to BELL.

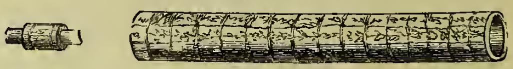
Engraving the Cylinders.—It has been stated that the first cylinders were formed of plates of copper bent round into a cylindrical form, and soldered at the edges. It is evident that to engrave such cylinders all over with the multitude of minute figures which exist in many patterns, must have been a work of great labour, difficulty, and expense. The cylinders, which vary in length from thirty to forty inches, and in diameter from four to twelve inches, are now turned from a solid piece of metal, accurately bored through the axis; and instead of engraving the entire surface by hand, the pattern is *impressed* upon them by a most ingenious transferring process, which greatly diminishes the expense. This process is so well described by **Baines**, that we cannot do better than give it in the words of that writer:—

The principle of this invention, says **Baines**, is the same which Mr. **Jacob Perkins** applied to the multiplication of plates for the printing of bank notes, and Mr. **Perkins** has the reputation of being its inventor; but the process had been practised in Manchester some years before he came from America to settle in London. Mr. **Joseph Lockett**, engraver for calico printers in Manchester, introduced this system about the year 1808; he may be considered as at least one of the inventors, and he certainly did more than any other person to perfect it. The method of transferring is as follows:—The pattern intended to be engraved is so arranged in the first place by a drawing made to agree with the circumference of the copper cylinder, as that it will join and appear continuous when repeated. This is then carefully followed by the engraver, and cut or sunk on a small steel cylinder, about three inches long and one thick, so softened or decarbonized as to admit of being easily cut. The steel is then tempered or hardened, and by means of pressure against another cylinder of softened steel, a fac simile is made *in relief*, that is, raised upon the surface. The second cylinder is then hardened in the same way, and it becomes hard enough to impress the whole engraving, even to the most delicate lines, on the copper cylinder, when pressed against it in a machine. The small cylinder originally engraved is called the *die;* the second cylinder, which is in relief, is called the *mill.* The latter is successively applied to the whole circumference of the copper cylinder, which is thus entirely covered with the pattern, as finely wrought as if it had been directly produced by the tool of the engraver. The surface of the die originally engraved is not more than about one-fiftieth part of the surface of the copper cylinder, and the engraving itself is therefore multiplied *fifty-fold.* By this means the most delicate designs, which would occupy an engraver many months to effect by hand, can be completed in a few days; of course the cylinders are produced at a much less price, and they may be executed in a very superior manner. Should the copper cylinder be so far worn as to require the pattern to be re-engraved, it can be done by the same process with amazing rapidity, and at a very trifling cost, as the mill is already prepared.

The annexed engraving—Fig. 376—exhibits the steel mill, A, on which the pattern is in relief, and from which it is transferred in intaglio to the roller, B. The die, which is a small roller, similar to A, is engraved by hand; all the rest of the operation is performed by transference.

Sometimes the die is cut on a flat surface, and the pattern transferred in relief to the mill by a suitable mechanism. In other cases the die is cylindrical, and the mill flat. The pattern is also sometimes produced by etching, in which case the polished cylinder having been heated, is covered with a thin coat of varnish, such as is used by historical engravers. The pattern is then traced on the cylinder with a diamond or steel point, and aquafortis is afterwards applied to the surface, by which the parts exposed become corroded or engraved. A complicated and ingenious system of tracing-machinery, invented by Mr. **Lockett** of Manchester, is capable, like the kaleidoscope, of producing an endless variety of patterns, which have the advantage at the same time of not being dependent on mere accident for the changes evolved. Eccentrically engraved cylinders, covered with a ground-work for patterns of great variety and beauty, are largely exported from Manchester, and the foreign printer adds the pattern to suit the taste of his customers. The electrotype has also been used for producing the design on the printing cylinder, but not hitherto with much success.

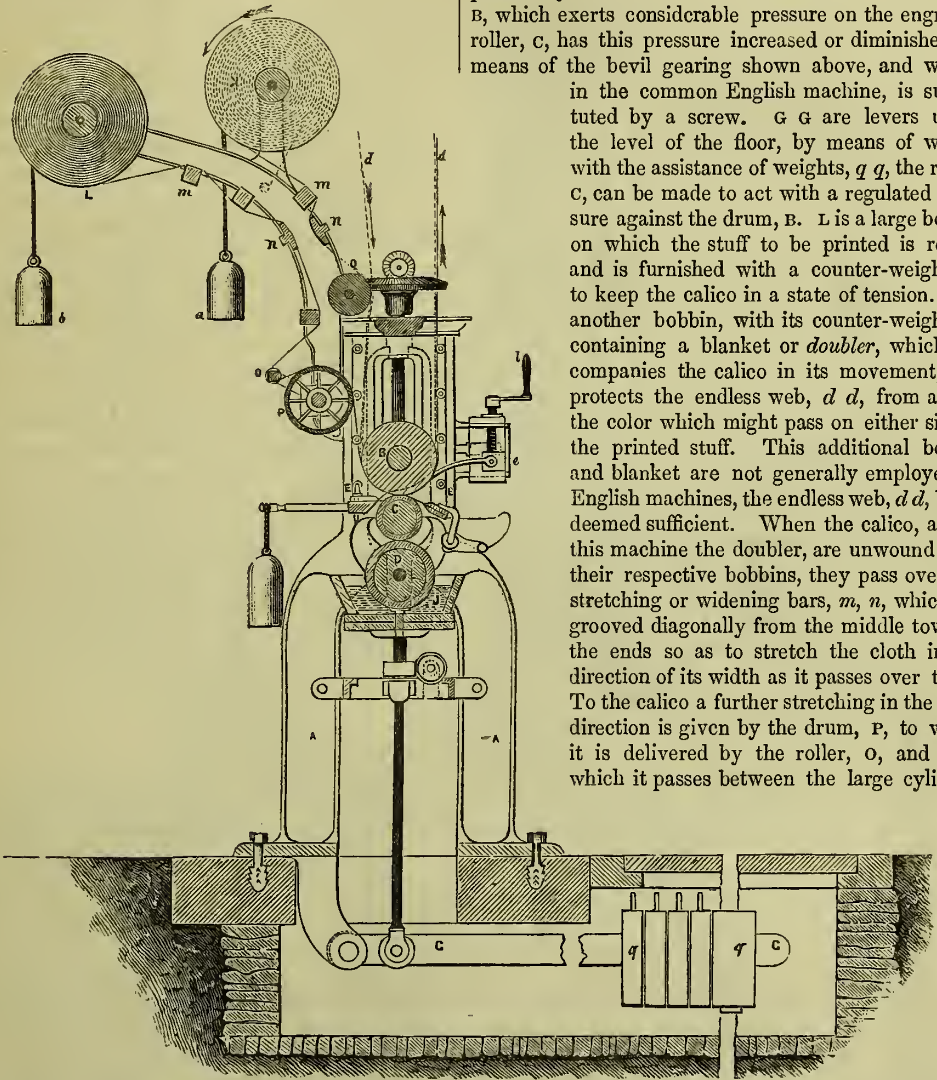
Fig. 376.



The English calico-printers possess a great advantage over their foreign competitors from the cheapness of engraving in this country, and the variety of patterns they can command. The English engraved copper roller is the best produced, and is an article of export to all parts of the world where printing is carried on. The French, with all their neat-handedness and ingenuity, says Dr. **Ure**, can produce nothing approaching in excellence to the engraved cylinders of Manchester—a painful admission, he adds, universally made to him by every eminent manufacturer in Alsace, whom he visited on a tour through that flourishing department. Copper rollers form a very important item of investment in the printer's capital, some of the larger print-houses holding stocks of engraved rollers valued by them in varying sums from £50,000 downwards. The value of one of these cylinders before engraving varies from £5 to £7, and the cost of engraving from £5 to £10. The engraving affords employment to a large number of skilled hands, capable of producing every variety of effect, equal to any efforts from the burins of the best engravers of the day.

Single Cylinder or One-color Machine.—The principles of the operation of calico-printing by the cylinder will be understood by reference to the annexed engraving—Fig. 377—which represents a vertical section of a French one-color machine, constructed on improved principles by M. **Huguenin**. It differs only in a few unimportant details from the common English machines, and is therefore selected as possessing some novelty for the English printer, while at the same time, for the general reader, it perfectly illustrates the principles of cylinder-printing. A is the iron frame-work; C, the cylinder or roller bearing the engraved pattern, and revolving in contact with the drum, B, on the one hand, and on the other with the color-roller, D. The latter is covered with stout woollen cloth, and works partially immersed in the color-trough, J, as shown in the figure. This trough rests on a plate which is raised or depressed by means of the screw under it. The drum, B, which exerts considerable pressure on the engraved roller, C, has this pressure increased or diminished by means of the bevil gearing shown above, and which, in the common English machine, is substituted by a screw. G G are levers under the level of the floor, by means of which, with the assistance of weights, *q q*, the roller, C, can be made to act with a regulated pressure against the drum, B. L is a large bobbin on which the stuff to be printed is rolled, and is furnished with a counter-weight, *b*, to keep the calico in a state of tension. K is another bobbin, with its counter-weight, *a*, containing a blanket or *doubler*, which accompanies the calico in its movement, and protects the endless web, *d d*, from any of the color which might pass on either side of the printed stuff. This additional bobbin and blanket are not generally employed in English machines, the endless web, *d d*, being deemed sufficient. When the calico, and in this machine the doubler, are unwound from their respective bobbins, they pass over the stretching or widening bars, *m*, *n*, which are grooved diagonally from the middle towards the ends so as to stretch the cloth in the direction of its width as it passes over them. To the calico a further stretching in the same direction is given by the drum, P, to which it is delivered by the roller, O, and from which it passes between the large cylinder, B, and the engraved roller, C. At first the latter was made to dip directly into the color-trough; but by the intervention of another roller, D, the color is more equally spread, and is forced into the lines or cavities of the engraving. By either method, however, it is communicated to the whole surface of the engraved rollers, whereas it is only required in the depressed parts that form the pattern. To remove it from the smooth surface, an elastic steel blade, E, reduced to so fine an edge as to take off the superfluous color without scratching the copper, is placed in contact with the cylinder, and another similar blade, which does not appear in this machine, is generally placed on the other side of the cylinder to remove any fibres it may have contracted from contact with the calico.

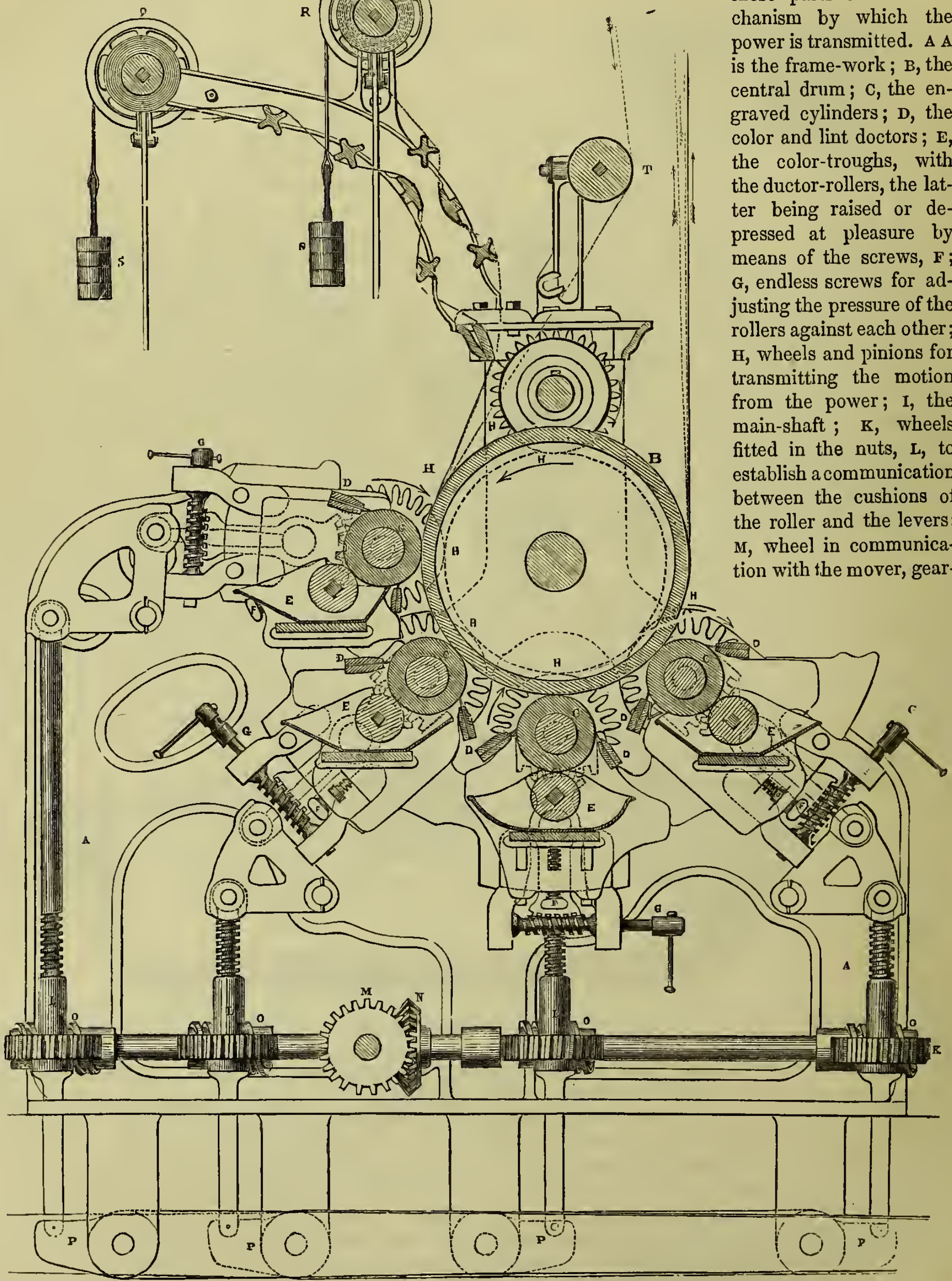
Fig. 377.



These blades have received the name of *doctors*, which, as BAINES remarks, may be a workman's abbreviation of the word *abductors*, applied to them from the purposes which they answer; or may have been given from a vulgar use of the word *to doctor*, meaning to set to rights. The one first mentioned is termed the color-doctor, and the other the lint-doctor. By a screw turned by the handle, *l*, acting upon the lever, *e*, any required inclination is given to the color-doctor; but these arrangements may vary according to circumstances. The doubler, passing round the stretching roller, Q, arrives with the calico under the drum, B, separating the former from the endless web, *d d*, the course of which, in connection with that of the other parts of the apparatus, is shown by the arrows.

French Four-color Machine.—The annexed view—Fig. 378—of another French machine, partly in section and partly in elevation, and calculated for printing four colors, may likewise be interesting to the English printer. The dotted lines exhibit a vertical section chiefly of those parts of the mechanism by which the power is transmitted. A A is the frame-work; B, the central drum; C, the engraved cylinders; D, the color and lint doctors; E, the color-troughs, with the ductor-rollers, the latter being raised or depressed at pleasure by means of the screws, F; G, endless screws for adjusting the pressure of the rollers against each other; H, wheels and pinions for transmitting the motion from the power; I, the main-shaft; K, wheels fitted in the nuts, L, to establish a communication between the cushions of the roller and the levers; M, wheel in communication with the mover, gearing with another wheel, N, on the shaft, by which it transmits its motion to the endless screws, O, gearing with the wheels, K; P, levers placed under ground, and charged with weights according to the pressure required; Q, a roller containing the stuff to be printed; R, a roller containing the doubler which circulates along

Fig. 378.

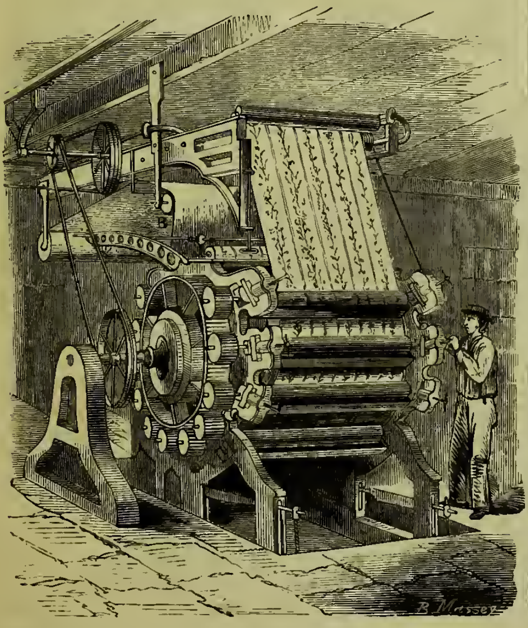


with the calico to protect the endless web from being stained with color at the margins; S, weights for keeping the calico and the blanket in a state of tension; T, a roller to guide the endless web in its course.

The action of this mechanism will be obvious from the explanation already given of the one-color machine. Each of the engraved cylinders, C C C C, contains only part of the pattern; and, supposing the colors in the pattern to be red, blue, yellow, and lilac, one contains the red, another the blue, the third the yellow, and the fourth the lilac parts. It evidently requires much care and attention so to prepare and adjust the cylinders that, as the calico proceeds round the drum, and receives the impression from each cylinder in succession, the different parts of the pattern shall fall into their proper places. When this adjustment, however, is once made, the action proceeds without interruption, and with the most perfect regularity till the whole is printed.

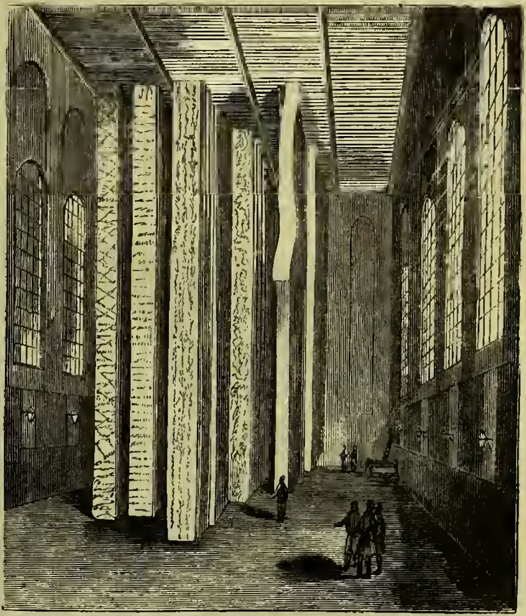
Latest Machines.—The preceding sectional figures sufficiently explain the principles of cylinder printing. Of late years, however, very great improvements have been effected in this mechanical department, and machines are now constructed which are capable of printing a great many colors. Fig. 379 represents an elevation of an eleven color machine, as working at the extensive and well-regulated establishment of Messrs. Hoyle and Sons, at Manchester; and Fig. 380 is a representation of a drying-room,. sketched somewhat hastily in the same establishment. Fig. 381, on the next page, is a delineation of a magnificent machine erected by Messrs. Mather and Platt of Salford, for Mr. Joseph Leese of the Ardwick Print Works, Manchester, ordinarily working with eighteen, but capable of printing twenty colors.

Fig. 379



When the difficulty of adjusting even a two or three color machine is considered, it will be evident to the reader that no small ingenuity must be displayed in fitting together the various parts of a machine for printing ten, twelve, or even twenty colors. In printing by hand, it is the operator who, by his carefulness and dexterity, gives to the patterns the correct character which constitutes beauty of workmanship; in cylinder-printing, it is on the regular movement of the machine, and on the quality of the colors, that success essentially depends. Now, in machines for printing several colors, the number, not only of the engraved rollers, but of all the other elements of the machine, is increased in the same proportion; since each cylinder must be provided with its color-trough, its ductor-roller, its color and lint doctors, and the other accessories connected with them. A large machine of this description becomes, therefore, a very complex piece of mechanism, requiring the most scrupulous attention, and very careful and accurate adjustment on the part of the superintendant. He has not only to regulate the working of each of the parts which co-operate towards the printing of one of the colors, but he must so adjust the movement of all the various parts of the whole mechanism, that each of the different colors may exactly fit into its place. This adjustment is often attended with much difficulty, on acount of the stretching of the stuff in passing successively under the different rollers. The endless web, also, is liable to deviate from its proper course, passing sometimes to the right, sometimes to the left, and drawing along with it the calico to be printed. Lastly, the engraved cylinders not having all the same diameter, cannot be moved with the same speed, and arrangements must therefore be made to regulate the movement of each. These are some of the difficulties which, among many others, so long retarded the application of many-color machines, and even

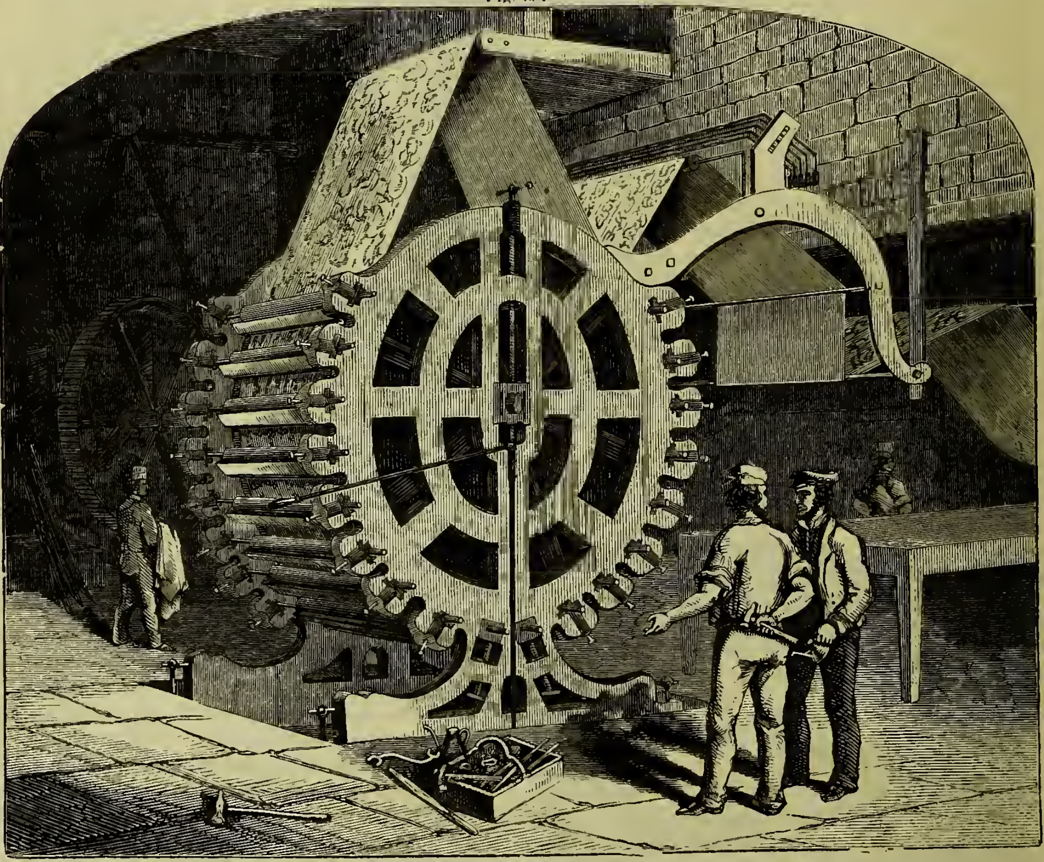
Fig. 380.



at first induced several printers to abandon the idea altogether.

To enable the attendant to adjust the engraved rollers in their proper positions, these rollers are furnished with marks placed at a part of the pattern where they can have no injurious effect upon the printing. In proceeding to adjust them, the overseer, applying his pencil, covers with a dark color the mark or *picot* of the first cylinder, to which he gives one turn; he then applies the pencil to the picot of the second, to which he also gives a turn, after having put it in connection with the first; and so on for the rest, till he has found the proper adjustment on the doubler or endless web. In this manner all the rollers are regulated according to the first; the printing of a piece is then commenced, but operating with so low a speed, as to allow of completing in all directions the adjustments which might not have been made exactly at first. For this preliminary trial, it is customary to make use of a doctor which performs the office of a color-trough. This, which is in front of the machine, is placed at the lower part of the cylinder, but making such an angle with it, that the space comprised between its plate and the surface of the cylinder may act as a reservoir for the color. Recourse is had to the same arrangement for printing expensive colors or those of which there is not sufficient quantity to fill a trough. Lastly, that the adjustment may be preserved during the course of a printing, it is requisite that the cloths be always well stretched.

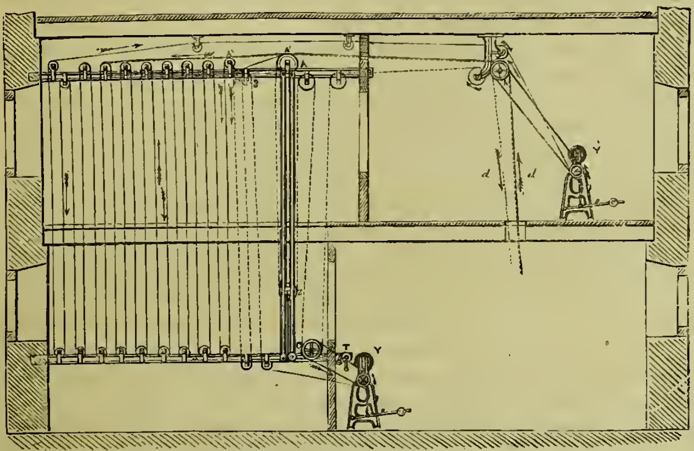
Fig. 381



It is more particularly in printing several colors, that it is essential for the calico and the doubler to have a regular movement, and that they do not become more stretched at some points than at others, between the cylinders. This kind of printing requires, moreover, that special regard be had to the order in which the colors should succeed each other on the stuff; for if, from want of precaution, a black color were printed before a red color, the color first laid on the stuff, arriving under the second pair of cylinders before being perfectly dry, would always be more or less transferred to the surface of these cylinders, from which it would pass into the red trough, and this last would soon print only brown-red, or puce. To be convinced of this it is sufficient to examine the samples printed twenty years ago by the two-color machine.

Besides these inevitable accidents occasioned by mixtures of colors, there are others which arise from the pressure A color too thin and too slow to dry, if printed by the first roller, would not remain at the surface of the stuff, but after being pressed between the second or the third cylinder, would penetrate through the stuff, and would then present only a poor and scratchy impression. The only means of abating these effects of mixture or of compression, is by composing patterns as much as possible in columns or stripes, choosing a thickening which shall have little permeability, and lastly, taking means to have the cloth as warm as possible. This last consideration merits serious attention. In printing with a single cylinder, very delicate patterns may be printed in thin colors, without fear of seeing the color run, for it is at once arrested and quickly dried on entering the drying chamber; in printing with several colors, if one wishes to prevent the transference of the color from one cylinder on to another, or the effects of the pressure on a color newly applied, which it tends to force into the pores of the stuff instead of allowing it to remain at the surface; lastly, if it be desired to obtain delicate impressions with the last as well as the first cylinders, it is indispensable to heat the cloth, otherwise the color, which must be applied thin, not being promptly arrested, would be pressed in or taken off between the other cylinders, and the pattern would lose all its clearness.

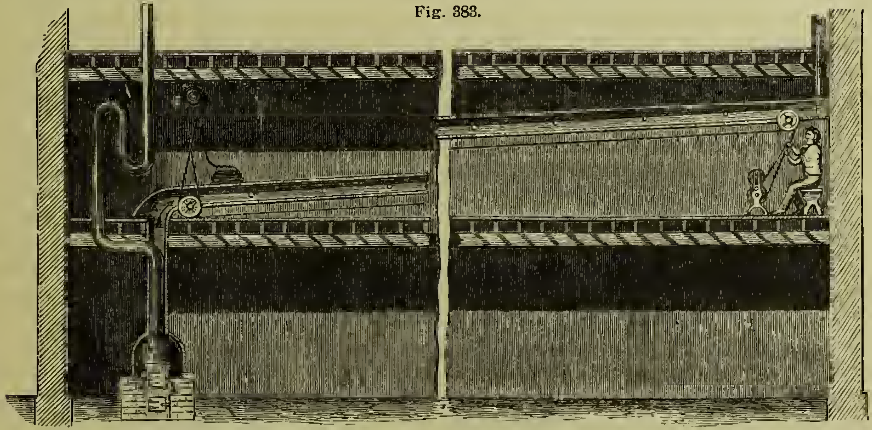
Fig. 382.



The many-color machine is, without contradiction, the most delicate of all the printing machines, and that which requires the greatest intelligence in its use; but, the printer who has studied it to the bottom, who knows its working, who knows how to bend it to all his requirements, to turn to account all its resources, possesses an immense advantage; for, not only does he derive benefit from the regular effects of the juxtaposition of several colors from those of their superposition, which has, for its result, the combination of one color with another, and the formation of a complex color, or the discharge or reserve of one or more colors, or lastly, the production of new colors by conversion, but further, he can give rise to an infinity of compound forms, by indefinitely combining the simple forms which are at his disposal.

Drying Arrangements.—The annexed engraving—Fig. 382—shows an arrangement for hard-drying the color or mordant, upon the stuff, as soon as it passes through the printing machine. This drying apparatus, in one form or another, is so essential that it is considered a part of the printing machinery. The course of the cloth, after passing between the drum and the engraved cylinder, is shown in the cut commencing at *d*, where it was broken off in Fig. 377, continuing for some time accompanied by the doubler and the endless web, and passing, by circuits, over a double row of rollers, till it is finally wound upon the bobbin, Y′, while the doubler is received upon another bobbin, Y, after having traversed only four of the rollers; and the endless web, constantly kept in a state of tension by a moveable pulley, Z, acted upon by the handle, T, returns under the drum, B—Fig. 378—after having circulated over some of the rollers. The doubler, as already stated, is dispensed with in English printing machines.

Fig. 383.



The Hot-Flue.—Under the name of the *hot-flue*, various methods of drying printed or padded goods at a somewhat elevated temperature, have been adopted; and one of the latest and most improved arrangements for this purpose will be given in connection with what is termed the *padding style;* but one of the oldest and simplest, and that probably from which the term itself, *hot-flue*, is derived, is shown in Fig. 383, where H is a round iron stove, from whose top a wide square flue, A K, represented, for want of space, as broken in the middle, proceeds upward in a direction slightly inclined to the horizontal. This flue is from twenty-five to thirty yards in length, a little broader than the common width of the stuff, and from twelve to sixteen inches in depth. At its lower part, A, it receives the current of air heated by the body and capital of the stove, H, and at its upper part, R, it communicates with the chimney, D. In this flue there are pulleys, with endless cords or bands, which suspend by hooks, and conduct the web of calico from the candroy or reel, O, where the operative sits to near the point, A, and back again. At A the drawing pulley connected with the main shaft is shown. One end of the moist calico upon the reel, O, is hooked by the operative to the endless band which draws it into the flue at R, and passing down the channel it encounters a current of air, hotter and drier as it proceeds, till arriving at A, or having been circulated a sufficient number of times, it is detached from the endless band, and taken up by a drum at E, from which it is deposited in a perfectly dry state.

PREPARATION OF THE COLORS AND MORDANTS FOR PRINTING.—To diffuse uniformly a color, or one of its components, such as a mordant, over the surface of a stuff, it is sufficient to convert either the one or the other into a liquid state, by means of a dissolving agent, so selected that it may not dispute with the fabric the power which the latter possesses of uniting with the tinctorial matter or mordant, and to impregnate the stuff with this solution under certain precautions; these are the operations daily practised in dye-works. But when, on the contrary, a color is to be applied on certain determinate points of the stuff, as in printing, to form a pattern upon it, more or less regular, it is a matter of absolute necessity that it be previously *thickened;* otherwise it would run or flow, and the patterns would lose their regularity, assuming both different shapes and different shades. Now, if to those who are little conversant with printing, it may seem to be an easy matter to accomplish this, namely, to give to the colors the degree of viscidity which they require to prevent their flowing—printers themselves express an opposite opinion. M. DANIEL KŒCHLIN, for example, says in his Memoir on Mordants, that the art of thickening mordants, or of giving them the consistence necessary to render them fit for different sorts of printing, demands long practice, and that, without doubt, in many cases, the success of the printing and of the combination of bases with the stuff depends upon it.

It would be in fact a perfectly erroneous idea of this operation, to think that every organic substance which possesses the property of giving viscidity to water, may on that account alone serve for the thickening of a color intended to be printed on cotton, silk, or wool. Sugar, for example, renders water viscous, and yet this body is excluded from use in the thickening of most colors, since the chemical action it exerts is such that a mordant mixed with it loses much of its affinity for the stuff. Many vegetal mucilages are known, and yet none can replace the mucilage *par excellence* which is yielded by gum tragacanth, because all of them produce the effect of masking a part of the chemical properties of the mordants, as tartaric acid, for example, and other fixed organic substances would do.

The first quality required in a thickener is, that it do not dispute with the goods the power of uniting with the coloring matters, otherwise, on removing the thickening, the color would disappear also. Thus, it would not be difficult, by modifying tartaric acid by heat, and rendering it uncrystallizable, to make it serve for thickening an aluminous mordant; but, in presence of that acid, the stuff would refuse to take on the smallest quantity of alumina.

Thickenings.—The substances which have been recognized as the fittest for the thickening of colors are the following:—1, Wheat starch; 2, Flour; 3, Gum-arabic; 4, British gum, or torrefied wheat starch; 5, Torrefied potato starch; 6, Gum-senegal; 7, Gum-tragacanth; 8, Salep; 9, Pipe-clay, mixed with gum-arabic or senegal; 10, China clay, mixed with gum-arabic or senegal; 11, Dextrin; 12, Potato starch; 13, Rice starch; 14, Sago, common and torrefied; 15, Sulphate of lead, mixed with gum-arabic or gum-senegal; 16, Sugar; 17, Molasses; 18, Glue.

In the choice which he makes of a thickener, the printer must be guided by several considerations; and the following excellent rules have been laid down by PERSOZ on this subject:—

1. He must take into account the temperature which the thickening of a color requires; for if the latter is of a nature to be decomposed by heat, starch and flours must be rejected, since these substances only incorporate well with the tinctorial matters, and thicken them properly, when mixed with them in a heated state.

2. The state of saturation of the color; for if it be strongly acid, starch and flours would be still less applicable to the purpose, as being too sensitive to the action of acids, all of which tend to liquefy or thin the colors which have been thickened with these substances, and to set up changes in them which vary every hour of the day. If, on the contrary, the color be alkaline, it will be necessary to ascertain whether it holds in solution earthy or metallic oxides. In the first case, all thickenings coagulable by alkalies must be excluded—such as the starches and flours; but gum, torrefied starch, and lastly, dextrin, may be employed; in the second case, all the thickeners which have just been mentioned, being of a nature to give rise to insoluble combinations with the metallic oxide, would be excluded, and recourse would be had either to sugar or to saccharate of lime.

3. Regard must be had to the combinations or decompositions which take place between the constituent principles of a color or a mordant, and this or that thickening, according to the nature of the mordant and the color, or according to their state of concentration. Thus, since the tri-acetate of lead precipitates, by its base, all the fixed organic substances with the exception of sugar, this last substance can alone be employed to thicken it. The salts of iron which coagulate the gums arabic and tragacanth, are properly thickened only by wheat and potato starch, torrefied starch, léiocom, and dextrin, which exercise no effect upon these salts; chloride of tin and gallate of iron, which are coagulable only by gum senegal, may be inspissated by all the other thickening substances; the acetates of iron and alumina, which neither coagulate nor precipi-

tate with any of the substances above-mentioned, may be thickened by any of them which one prefers to employ. With regard to astringent matters, or such as are rich in tannin, as these have sometimes a tendency to cause colors to coagulate, it is necessary either to employ suitable agents to prevent this—acetic acid for example—or to change the thickening.

4. The degree of consistency which is to be given to a color to make sure of its taking on, must likewise be considered; for the rapidity with which it dries may exercise a great influence on its intensity, when it has been formed and fixed on the stuff. Thus, iron and aluminous mordants strongly thickened with gum, and consequently of a nature to dry with great rapidity, produce on the stuff shades incomparably less full than the same mordants employed in the same degree, but thickened with starch and of greater consistence.

5. The intensity of the shade which it is desired to obtain must be taken into consideration; for *cæteris paribus*, a mordant of the same strength, thickened with gum tragacanth and with potato starch, gives shades infinitely more intense than that which has been thickened with gum arabic and with torrefied starch, for this reason, that under the same volume of liquid or of mordant there is much less of fixed organic matter when the gum tragacanth and starch are employed, than when use is made of gum arabic or of torrefied starch. Let it be desired, for example, to thicken one gallon of acetate of alumina to 5·5 Twaddell, in this case nine to eleven ounces of gum tragacanth would suffice to bring the color to the desired consistence, whilst it would require about twenty-four ounces of starch—in reality twenty ounces of solid matter, the starch usually containing eighteen to twenty per cent. of water—and to attain the same consistence one must employ at least fifty-seven ounces of gum arabic.

If the intensity of the colors furnished by a mordant is in inverse proportion to the quantity of solid matter which it requires to be properly inspissated, the cause of this may be found partly in the property possessed by fixed matters of masking a certain quantity of the mordant, by forming with it a combination on which the stuff is without action, and partly in this fact, that a color which, under the same volume contains less of solid matter, always undergoes by desiccation a kind of concentration or shrinking much more considerable than when the thickening is strong.

6. Regard must be had to the hue of the thickening; for, although when it happens that a color applied and fixed on the stuff resists all the mechanical operations of the scouring by which it is cleared of the thickening that has been employed, one is in that case relieved from the necessity of attending to the more or less colored state of this thickening, yet, when the color, on the contrary, does not resist a thorough scouring, and a certain quantity of the thickening remains adherent to it, the case is different. It is absolutely necessary, indeed, to abstain from inspissating delicate colors by means of colored thickenings which would injure them by adding their own shade. If torrefied starch, for example, be used to thicken rose or blue, to be then printed on a woollen stuff, on which neither of these colors will very well resist washings, the consequence is that by combining with the yellow-brown tint of the thickening, the first will become brownish and the second greenish; but, on the contrary, the same thickener is advantageously employed for thickening the same colors on calico, on which they become definitively fixed, only after the stuff has been perfectly scoured.

7. The facility with which a thickening may be discharged from the stuff must also be taken into account; and it will at once be seen that this consideration is intimately connected with the preceding, namely, that a colored thickening ought to be employed more rarely in proportion as there is greater difficulty in removing it by the washings; at the same time, attention must be given to the fact, that a thickening, even when colorless, sometimes produces the effect, according as it remains adherent or not, of causing the stuff to contract properties which diminish its value. M. D. Kœchlin-Schouc has, in fact, shown that gum Senegal employed as a thickener, combines in so intimate a manner with the stuff and with the mordant when it has undergone an acid fermentation, that it can no longer be discharged from the goods by the ordinary means, and gives them a stiffness or rigidity which always compromises the operations of the printing and dyeing.

8. Regard must be had to the shrinking or contraction which the thickenings cause the stuff to undergo, when several colors are to be successively printed. If, indeed, a gummy substance spread on a piece of wood or sheet of glass always cracks on drying, in consequence of such surfaces presenting too much resistance to follow the film of gum in its shrinking movement, a quite different result is the consequence when this solution is printed, in any quantity, on goods which yield by their softness to the contraction of the gum, and thereby acquire wrinkles or creases always more or less prejudicial in the printing of different colors. These accidents are usually prevented by the use of a mixture of thickenings which do not produce this shrinking movement, at least not in the same degree, or by employing pipe-clay, which acts in this case a purely mechanical part, by rendering the gum less persistent.

9. Attention must be given also to the order in which the colors are superposed in the printing; for very often, when one is obliged to print several mordants alongside one another, the engraving must be so combined as to prevent, by a superposition of the light on the dark color, those breaks of the continuity to which the slightest inattention on the part of the workman would give rise, if the mordants were only put in juxtaposition to each other. It is obviously essential, in this case, that the thickenings be not of such a nature as to react on each other and thus to confound the colors. The first color that is printed of a pattern is usually the darkest and the thickest; it is thickened with starch, and the second with gum. In the case of delicate cylinder printing, the first color is thickened with roasted starch, British gum, or dextrin, and the printing of the ground with gum Senegal.

10. The nature of the engraving must be taken into account; for when the lines are very fine and the work elaborate, it is evident that coarse substances cannot be used as thickeners. On this subject it may be suffi-

cient to remark, that the printing of a delicate pattern is always performed with infinitely better chances of success by means of gum arabic or torrefied starch, than with starch in the crude state, or flour; on the contrary, if the pattern has massive parts which should stand out in relief, the starch and flour will perfectly meet the views of the printer. In short, it may be stated as a general rule, that when the engraving is of little depth the printing should be done with colors or mordants but little thickened; when, on the contrary, it is deeper, one should employ thick colors; nevertheless, there are limits on both sides which must not be exceeded. When the pattern is composed of very deep parts along with others which are of little depth, it is necessary to employ a certain proportion of starch, or to add to the color, if gum be used, a substance which will give it sufficient body to ensure clearness and equality of impression in the deep lines, leaving it at the same time thin enough for that of the light lines.

11. The manner in which the thickening behaves in presence of a color or mordant is another point of importance, for it is essential to good results that the latter should remain during the whole time of its being printed at that degree of consistency which has been given to it by the thickening; otherwise, if it should become thicker or thinner, the influences of these variations would manifest themselves in the printing in a very annoying manner; such variations are prevented by the intervention of a suitable substance added in very small quantity. It will be sufficient, for example, to add a little gum or starch to prevent coagulation.

12. Lastly, besides the necessity of attending to the qualities of the gums and starches employed, an important element for consideration in making a selection among them, is sometimes the cost. When gum can only be procured at a high price, several printers endeavor to replace it by other thickenings in almost all the colors with which it is used.

To these considerations it may be added that pipeclay is employed not only to prevent the too powerful shrinking of a color, which has the effect of contracting the goods, but further, to prevent the running or flowing of a too thin color, and thus to confine it to the spot on which it is deposited by the printer, as well as to aid in the scouring of the color, which it always renders more easily acted on by water. Gelatine is also employed as a thickening, having the effect of giving more body to the color, without sensibly increasing the weight of the solid matter which thickens it, while at the same time contributing, by the modifications which it undergoes in presence of an acid, to render the color hygrometric. With the same view, and also with that of opposing the coagulation of a color, the chloride or the nitrate of zinc are likewise employed; and lastly, saccharate of lime.

Having thus stated the nature of the different thickenings, and those considerations which ought to determine the choice of them by the printer, the Editor now proceeds to explain the processes to be followed for the thickening of a color, and to lay down in a general manner the quantities of thickenings which it is proper to employ according to circumstances.

When gum arabic is used, it is either dissolved in water, so as to form a concentrated solution which is left to settle, then filtered if necessary, and added in suitable proportions to the mordant or color to be thickened; or the gum is added in a crushed or pulverized state to the color itself, to dissolve in it either cold or hot, according to the nature of that particular color. In the first case, pieces of gum, as they are taken from the casks, are placed in a basin, and after being simply wetted, they are shaken together so as to detach by their mutual friction an opaline substance which tends to set up the fermentation of the gum, and its passage to the sour state.

The colors with which starch is used are thickened also in two ways: either the starch is made into a very dense jelly, and the color to be thickened then incorporated with it—a process however, which is rarely employed—or the starch is mixed with the liquid and all or part of the ingredients which should enter into the color; the mixture is then heated, stirring it till the starch becomes gelatinised; and lastly, the color is boiled, for ten, twenty, thirty, to forty minutes, according to its nature, as well to give it homogeneity as to render it more fluid; for many colors are much thicker at the moment when the starch has just jellied than after boiling, which may be attributed to two causes: first, to the effect produced by the heat on the jelly, which liquefies in the long run; and secondly, to that attraction which the acids contained in a color may still exercise upon it. Further, it is always prudent, when acids are to enter into a color, not to incorporate them with it till after the thickening has taken place. The mixture when sufficiently boiled is withdrawn from the fire, and, either immediately or after it has cooled a little, the complementary ingredients are added; lastly, according to its constitution, it is either left to itself, or carefully stirred during the whole time it is cooling. This precaution is particularly indispensable in thickening aluminous mordants, which become turbid by heat, otherwise, the sulphate of aluminia precipitated would only be imperfectly redissolved, and the color would be a complete failure.

The operation just described is performed, either on the open fire in copper pans or boilers, or by the aid of steam in double-bottomed vessels of that metal. Formerly in every color-kitchen, so called, there was placed a series of pans and furnaces to correspond, of a capacity increasing by gradations from half a gallon up to thirty and fifty gallons. In these vessels one or two workmen, armed with strong wooden spatulas, agitated and stirred the color during the whole time which preceded the formation of the jelly, to prevent it from clotting, and also from sticking to the bottom and burning during the boiling. To diminish the trouble and inconveniences attending this operation, thickening by steam has been generally substituted for that by the open fire, as the use of steam secures the printer against the risk of his colors or his prints turning out failures from being exposed to the action of a too powerful fire, or from the negligence of the workman, who may not have agitated his color with sufficient care.

In the French printworks, they have retained the old arrangement of the vessels for boiling the colors, but these, consisting of a series of double boilers of different capacities, are made to communicate with each other and with a steam generator, which transmits to them the caloric necessary for the formation and boiling of the starch-jelly. The vessels are further furnished at their lower part with a tube which allows the water of condensation to run out. For this arrangement of double-bottomed fixed boilers, which are always more or less difficult to empty and clean out, the English printers have substituted a system, by which the coppers are movable, and accessible on all sides to the workmen. This arrangement is shown in Fig. 384. A is a wooden platform, serving for a support to the whole apparatus. B, B, iron pillars with cushions, on which the bearings of the coppers turn. C, C, openings on the pillars, B, furnished with lunettes, to which are fitted tubes for receiving the steam, Fig. 385, which is distributed under the coppers by means of double and single stopcocks. E, double coppers, the structure of which is represented in Fig. 386. These coppers turn on hollow bearings, which, being jointed into one another by tubes, themselves turning in stuffing-boxes, establish a communication between them, and allow the steam to circulate from one double-case into another. F, stopcocks, by which issue is given, from time to time, to the water which proceeds from the condensation of the steam, and which falls into a tub placed immediately under, or runs into a general reservoir; G G, iron handles fixed to the boilers, and which afford to the workmen the means of inclining them at pleasure to pour the color into the tub placed almost immediately under. It is obvious that by means of the openings, C C, placed in each pillar, and the stopcocks, which allow of intercepting at pleasure all communication between two or more coppers, the option is given to heat only the number of coppers that may be required.

Fig. 384.

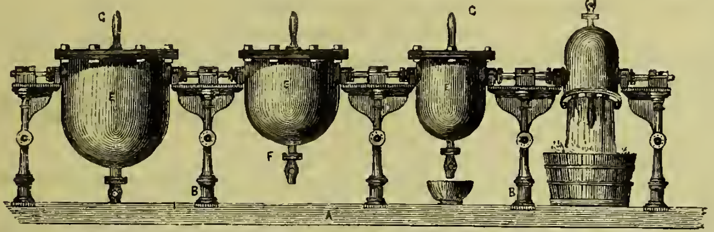


Fig. 385.

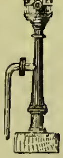
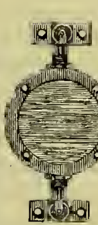


Fig. 386.



Some printers, who had adopted this system, have replaced it by fixed coppers seated in masonry, to prevent both the too rapid condensation of steam which takes place when the vessels are free and exposed to contact with the air, and the escapes which the tension of the steam often causes from the stuffing-boxes. It appears, however, that one might arrive at the same result, and retain the advantage of having the boilers movable, by giving more care to the construction of the stuffing-boxes, and surrounding the lower part of the apparatus with bad conductors. For the rest, there is always an advantage in collecting the distilled water which the condensation of the steam yields, and which may be turned to account for various purposes.

Whether the colors have been thickened on the open fire or by steam, and whatever precautions may be taken, clots, or lumps, are always formed, which it is important to get rid of. For this purpose they are poured in small quantities on a sieve, with meshes of more or less width, through which they are forced by a workman, who rubs them against the sieve as they pass, by means of a brush.

Sometimes they are poured into a large square piece of cloth used expressly for this purpose, and two workmen, by wringing this cloth in the direction of its length, force the colors through its meshes; in other cases, they are *panned*—that is to say, they are introduced into pans or cylinders, in which motion is communicated to balls or bullets, by which they are crushed and comminuted.

When the colors are thickened with roasted starch, with léiocom, or potato-starch, the operation is usually performed in the cold, and in the following manner:—The thickening is poured into an earthen pan with the quantity of liquid necessary to make it into a soft paste; it is worked well to get rid of all the hard parts, and then the rest of the liquid is gradually incorporated with it. If the starch was not completely and uniformly torrefied, the color must be heated and gently boiled, being always guided on this point by the preliminary trial which ought to be made of these substances before using them. This kind of thickening, more than any other, requires that the colors be perfectly *sifted* or *panned;* for the fragments of charry matter or hardened gluten which are met with in it, may very often give rise to accidents more or less serious, especially in cylinder printing, as well from the effects which these substances produce on the engraving, as by the obstacles which they present to the highly important function of the doctors or scrapers.

Gum tragacanth is employed, either as a mucilage or in powder; in the former case, it is sufficient to steep it in a certain quantity of water, in which it swells up, to prepare it for being added to the colored liquor to be thickened; in the second case, it is incorporated with the liquid, taking the precaution to sprinkle it with a little alcohol. It is rarely that this gum is employed alone; for all printers have observed that, while it communicates more vivacity and brilliancy than other thickenings, it imparts to the colors neither the necessary body nor the requisite binding quality, and this consideration, added to reasons of economy, has led to the practice of associating with it a certain quantity of gum arabic or white starch, or a mixture of these two substances.

The quantities of thickenings to employ vary with the nature of the colors, the mode of printing, the depth or lightness of the engraving, and, lastly, with the season of the year at which the printing is performed; for the same color requires different proportions of thickenings in summer and in winter.

To thicken colors or mordants, the average quantities required are as follow:—

If white starch is used, twenty-five to thirty ounces of this substance to the gallon of color. The proportions vary between these two extreme quantities; the highest is suitable for colors to be printed with the block; the lowest for cylinder printing.

If roasted starch or léiocom be used, 5·5 to 7·5 lbs. in winter, and in summer nine to eleven lbs., to give to the color when printed with the block the density which it requires, and about one-fourth less if the same color is printed with the cylinder.

If gum senegal is employed, forty-five to fifty-five ounces per gallon to thicken the mordants of alumina; one hundred to one hundred and ten ounces for violet mordants; but these proportions vary also with the season, and especially with the nature of the pattern and the depth of the engraving. Thus,

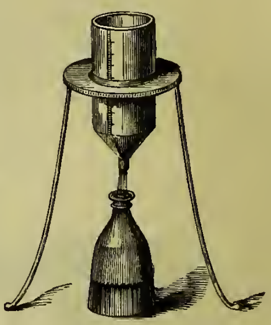
	For a printing in picotage or mignonette pattern.	For a printing with deep lines
Violet requires per gal.,....	5·00 lbs. of gum.	6 20 lbs. to 6·80 of gum.
Red,.........	3·45, 3·75, 4·00	4·50
Rust-color,....	4·00	5·00
Crockery-ware blue,.......	4·00	5·60

If gum tragacanth is employed, four to five and a-half ounces per gallon of liquid, with double that weight either of gum arabic, or of starch, or, which answers still better, equal parts of starch and gum arabic, that the color may be perfectly fixed. Some printers use a gum water formed of 1 gallon of water and 10 ounces of gum tragacanth with 10 ounces of gum arabic.

It is proper to remark that colors thickened with flour must be boiled for at least an hour to an hour and a half, to give them the homogeneity which is desirable, and that these colors always work better after being some time prepared than when they are recent. Those which are thickened with starch do not require so much boiling; nevertheless it is always useful to boil them so long as to prevent their turning. Starch strongly roasted is, *cæteris paribus*, always employed with much greater success than that which is less so, as it renders the colors less liable to coagulate. Torrefied starches, *et cetera*, employed in the printing of aluminic and ferrous acetates do not give so good results, but they answer perfectly for printing blue, fast green, and aluminate rose.

Viscosimeter.—In proportion as the cylinder has been more generally introduced, the printer has felt the necessity of estimating the degree of viscosity of the color thickened with gum and torrefied starch, which are generally used for this kind of printing, so as to be able at need to give it the most suitable consistence; for we know that this viscosity must necessarily vary with the depth of the engraving, with the nature of the pattern, with the season, with the hygrometrical state of the atmosphere, and, lastly, with the quality of the goods. It was to meet this requirement that M. CHARLES DOLLFUS constructed the *viscosimeter*, based on the consideration, *that the thicker a color is, the less liable is it to run, and vice versa.* This apparatus is very simple; it consists in a cylinder—Fig. 387—of four inches in diameter by twelve in length, terminating at one end in an open cone of five to six inches in length, which gives it somewhat of a funnel shape. To the mouth of this cone is fixed with sealing-wax a glass tube presenting an opening of about one-tenth of an inch in diameter. This species of funnel, which is graduated for introducing into it given volumes of liquid, rests on a tripod standing pretty high, to admit of being placed over a decanter. After filling the apparatus with water up to the mark corresponding to one quart, the liquid is allowed to flow out by the lower opening, determining with watch in hand, the time it takes to flow, to regulate this opening in such a manner that one quart of water may require just two minutes to flow out, a condition which M. DOLLFUS found to be most suitable for studying the rates of flowing of the lighter and thicker colors; then, having finished this preliminary operation, the operator introduces successively into the apparatus one quart of the different colors whose degree of viscosity is required, and it is necessary only to note each time the period occupied in the flowing to establish a scale containing all the degrees of thickening in relation with the patterns, the engraving, and the stuff to be printed.

Fig. 387.



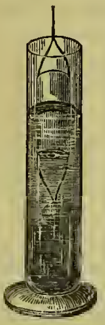
It is needless to say that, in all these valuations, it is important to keep an exact note of the temperature, since the heat, by considerably modifying the viscosity of the colors, causes considerable variations in the time of flowing.

M. HENRI SCHLUMBERGER pointed out the principal disadvantages of this apparatus, and proposes to substitute a glass funnel for the metallic cylinder when the colors are of such a nature as to corrode it.

M. DOLLFUS D'AUSSET, on the other hand, struck with the differences which occur in the duration of the flowing, according to the change of level in the column of color, conceived the idea of determining this efflux by keeping the column of liquid which presses on the orifice at a constant level, by means of a reservoir placed alongside the funnel, and in communication with it. The apparatus being thus constantly filled up to the same level, the efflux proceeds, and by weighing or measuring with exactness the quantity of color which escapes in a given time, the degree of viscosity is determined in a pretty accurate manner.

Of late years, M. IVAN SCHLUMBERGER has published an extremely simple instrument which now satisfies all the requirements of the printer in reference to this matter. It is a kind of areometer—Fig. 388—loaded with a weight for sinking into the liquid the viscosity of which it is desired to estimate, and the hollow cylinder is pierced at its lower part with an aperture of small diameter, which, allowing passage to the liquid the more readily in proportion as it is less viscid, affords the means of establishing the relative viscosity of the colors according to the time which they take to fill the vessel.

Fig. 387.



The same instrument is employed to estimate the relative value of the gums; but while it admits of determining the viscosity which they impart to a liquid, it cannot, in any case, indicate their degree of purity; for example, a senegal gum mixed with a certain quantity of British gum, which is much more mucilaginous, will always give by the viscosimeter a much thicker solution than pure gum-senegal. The fact, therefore, must not be lost sight of, that in all the valuations of the gums made by this process, the gelatinous state of these substances must be taken into consideration.

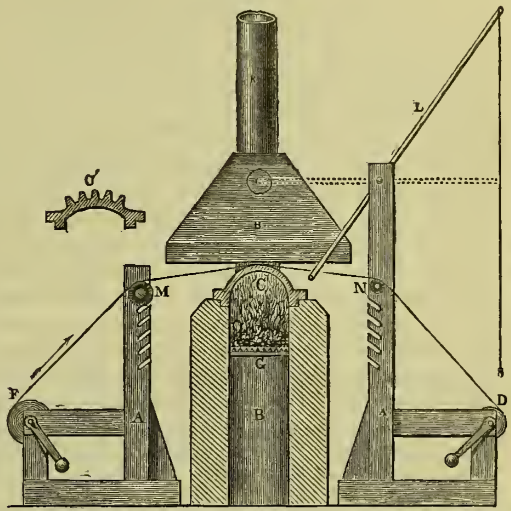
Sightenings.—When the mordant to be printed is colorless, or nearly so—as alum, red liquor, and salts of tin—it is mixed with some fugitive coloring substance, called a false color, to render the design on the cloth more perceptible, that the printer may be able to follow his work, to detect defects when they occur, and to apply a remedy to them. This addition of the false color is called *sightening.* The substances usually employed for this purpose are of several kinds: they are sometimes colored insoluble substances in a state of extreme division—such as charcoal and indigo—which are afterwards easily removed by a thorough washing; sometimes other colored preparations—such as decoctions of logwood, campeachy, Brazil wood, and even sulphate of indigo—some of which are not always got rid of with the same facility after they have served their purpose.

Preparation of the Cloth for being Printed.—The object of the first operation to which cotton goods are subjected, whether intended to be afterwards printed or merely dyed, is the removal of the fibrous down or nap, and the small asperities or knots, which always exist to a greater or less extent on the surface of the cloth, however carefully manufactured by the most improved methods. This is effected by the process of *singeing,* which is generally performed on all goods about to be submitted to the operations of bleaching, and has therefore been briefly adverted to in the article on that subject.—See page 303. For goods merely intended to be dyed, the singeing may sometimes, though rarely, be dispensed with; but it is essentially necessary with a view to the printing, and therefore it has been judged best to reserve a particular description of the operation for this place.

The process of singeing may be performed by either of two different ways—one of which consists in drawing the cloth rapidly over a red-hot semi-cylindrical bar or sheet of copper, and the other in passing it quickly through a coal-gas flame. It may seem surprising to the reader, and still more to one who witnesses the process, that either of these operations can be performed on the stuff without injury to the fibre; but the truth is, that the different textile fibres are capable of supporting a pretty high temperature without being decomposed, and are, of all bodies, the worst conductors of heat, while the motion communicated to the stuff is so rapid that only the external fibres have time to be burned or singed off.

Hot-plate Singeing.—The method of singeing by passing the cloth over a red-hot surface is shown in Fig. 388, which exhibits a vertical section of a singeing furnace. B is the ash-pit; G the fire-place communicating with a vaulted horizontal flue, somewhat exceeding in length the ordinary breadth of the cloth. This flue terminates in a chimney, R, and is covered on the top with a semi-cylindrical plate, or bar, of copper or cast-iron, C, four feet in length by nine or twelve inches in breadth. Iron was formerly used, and in that case the bar was two inches or more in thickness; but preference is now given to a bar of copper, three-quarters of an inch thick, the latter being found to last much longer than the former, and to singe nearly three times as many pieces of cotton with the same consumption of fuel. With a copper bar, about fifteen hundred pieces may be singed by a ton of coals in a well arranged furnace. In some establishments, the bar is formed, as shown at C′, with five prismatic ridges. F D are winch-rollers on which the goods are wound, being previously connected together into one long piece, and fastened at both ends to other pieces of cloth, attached to the winches, so that the whole of the goods may pass over the hot plate from end to end. A A are wooden supports, bearing cylindrical brushes, M N, for raising the nap or fibres of the stuff as it passes over them; and these brushes may be raised or depressed to bring the cloth into shorter or longer contact with the plate, C. To one of the uprights, A, is fixed a lever frame, L, by which the cloth may be lifted off the bar or let down upon it at pleasure, by simply pulling its cord; and in the funnel, H, which is intended to convey the vapours produced by the ignition into the chimney, are two slots to allow the frame to be raised or depressed for this purpose.

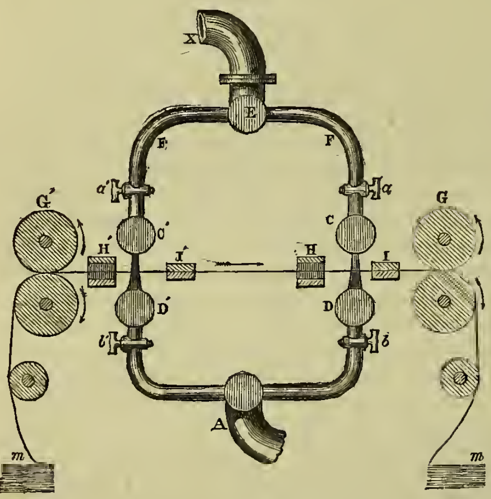
Fig. 388.



The iron or copper bar is brought to a bright red, and the goods being wound upon one of the rollers, F, and connected with the other, D, are kept in a state of suspension by the frame, L. When all is ready, they are let down upon the bar, and, at the same moment, the roller, D, which is kept wet, is turned, either by the hand or by power, and kept steadily revolving at that speed which the experience of the attendant informs him to be necessary. The cotton is generally passed over the bar three times—twice on the *face*, or the side which is to be printed, and once on that which is to be the *back*. By this operation the color of the calico becomes very similar to nankeen.

Gas Singeing.—The other method of singeing consists, as has been stated, in passing the cloth quickly through a gas-flame—a method for which a patent was obtained by Mr. SAMUEL HALL, of Basford, near Nottingham, in 1818, and which has now generally superseded the red-hot plate. The gas issues from numerous perforations through the upper surface of a horizontal tube, and the cloth to be singed is drawn rapidly over the flame by rollers. In the method first patented, the flame was drawn up through the web of cotton or other fabric by a flue leading into a common draught-chimney; but the draught not being always sufficient to draw the flame through immediately, an improvement in the apparatus was devised by Mr. HALL, and patented in 1823, which consisted in placing immediately over the gas-flame a horizontal tube, with a slit lengthways through its lower surface, which tube is placed in communication with a fan or an exhausting apparatus. This arrangement is shown in Fig. 389, where A is the principal pipe, which, by the two branches, *b b′*, distributes the gas to the two horizontal tubes, D D′. These tubes, which are seen only in vertical section, are long enough to extend to each side of the broadest webs. The perforations in their upper surface are very close to each other, and in a straight line, so that the gas forms, as it were, one long flame. Immediately over them are two other horizontal tubes, C C′, with the slits in the lower surfaces exactly corresponding to the two flames, and communicating by the branches, F F′, with the larger pipe, E X, connected with a suction-pump, or hydraulic apparatus, for exhausting the air. G G′ are two pairs of wooden rollers covered with cloth, and which, when turned, communicate to the cloth a speed of about three feet in the second. H H′ are brushes placed before the flames, assuming the course of the cloth to be, as indicated by the arrows, from *m′* to *m;* and I I′ are rubbers, covered like the rollers with fustian, to extinguish the sparks which might be carried along with the stuff. A partial vacuum is first created by some suitable apparatus in the pipes connected with C C′; the stopcocks, *b b′*, are then opened, the goods put in motion, the gas lighted, and the stopcocks, *a a′*, opened, when the flames rush into the tubes, C C′, passing sheer through the cloth, which moves, however, too rapidly to suffer damage.

Fig. 389.



Bleaching.—After being singed by one or other of these processes, the goods are bleached, except when intended for Turkey-red dyeing, or a dark ground, in which case the stuffs are treated in their natural grey state. As a general rule—that the colors of the tinctorial matters applied to tissues, whether by dyeing or printing, may appear in their purity, it is essential that the cloth be wholly freed from the foreign matters which adhere to its surface, whether imparted in the processes of spinning, weaving, *et cetera*, or else naturally adherent to the fibre of the cloth. In cotton goods, or calicoes, this is accomplished by the process of bleaching by means of chlorine; and in silk and woollen goods by the action of sulphurous acid, as fully described in the article BLEACHING.

Calendering.—When the stuff has been freed of its nap and knots by singeing, and afterwards well bleached, it must still undergo, before being printed, the operation of calendering, which has for its object to render the surface of the stuff more apt to receive the color or mordant uniformly, and to make it more easy to operate. This process has likewise been described in a previous article—see page 318—and consists essentially in passing the goods between cylinders of metal or of pasteboard, which, by subjecting them to a powerful pressure, communicate a gloss to their surface. As this operation cannot be performed without in some degree stretching the stuff both in its length and breadth, this effect has been turned to account to smooth, by a proper pressure on certain points, the parts of a web which may have undergone unequal contractions.

If the calendering is an element of success in the printing in all those cases in which the stuff is destined to receive immediately, one after another, the different colors of which a pattern is composed, it ceases to be so when it receives at one time only a part of the colors which are to figure upon it, and then has to undergo the operations of dyeing before the printing of the *re-entering colors;* for as the goods which the calendering has stretched, contract and shrink by the subsequent operations of dyeing, washing, and scouring, it often becomes very difficult to re-enter a color upon them in the very place it should occupy. This re-entering is generally termed in Lancashire *after-grounding* or *blocking-after*, the operation being performed by hand with small blocks. If the operation of calendering has been well performed, the stuff exhibits no defects, and can be brought back to its original state by a regular stretching in length and breadth, or the effects of the shrinking compensated by a proper arrangement of the engraving. When, on the contrary, the calendering has been badly performed, and the web is unequal, none of these contrivances will avail, and the printing, in a mechanical point of view, is always defective. In general, therefore, looking to these considerations alone, the printer cannot give too much attention to the choice of his goods, and to the operations which precede the printing of them, and which may give rise to an irregular contraction of the stuff.

When the goods, before being printed, have already passed into the dye-becks, and it remains to print on them re-entering colors with the block, they are still calendered, but much less than the white goods, since the dyeing, the washings, and often also the printings of the stuff having deranged the square of the pattern, the printer finds himself obliged, in order to apply his block well, and re-enter his color within the *contour* of that which is already fixed, to stretch the stuff both lengthwise and in its breadth, according to the irregular contractions it has undergone, which he would find more difficult to do if the stuff had been much calendered.

The goods which are destined for cylinder-printing ought to be, more than any others, free from knots and nap, which would act as a resist upon the delicate patterns usually printed in this manner. Nevertheless, as they should possess a certain elasticity, one must be cautious in submitting them to the calender. When the machine is not furnished with a stretching drum, they are made to slide over widening rules fixed in a bar-like apparatus, from which they proceed to be wound up on a roller, placed at the opposite point from where they arrive, and a workman has the charge of beating them carefully with a rod during this passage, to cause the dust and dirt to fall from them. It is from this roller that the stuff is unwound to pass under the engraving cylinder.

Damping.—The goods, when about to be printed, should likewise have a certain degree of dampness, to give them all the elasticity they admit of, and sufficient adhesiveness to the colors. It is doubtless from this indispensable condition that several printers, attributing to the electricity of the atmosphere an influence which it really does not exercise, are still questioning whether it be possible to attain an entire regularity in cylinder-printing. Doubtless, in a dry state of the weather, one may draw from the printing machine very powerful sparks of electricity; but all that this peculiarity proves is, that the worst conditions for successful printing then exist; that the articles and the air are then dry instead of being moist; and hence the development of electricity, far from being the cause of the accidents which supervene, is only the effect of the abnormal condition in which the process is carried on.

It is not sufficient, moreover, merely to recognise the necessity of damping the goods; it is necessary further to employ the most suitable means for attaining that end. In some cases, at the time of being rolled up, they are sprinkled over with water, or made to imbibe moisture by means of wet yarn; then they are left some hours at rest, to give the water time to spread itself uniformly. But this, and most other methods employed, present the disadvantage of wetting the goods too much at certain points and thus producing runnings, or giving rise to an unequal impression, either because the water has not penetrated equally all parts of the stuff, or because the repose of a few hours to which the goods were left on being rolled up, was sufficient for the air to dry them at the edges. In some print-works they place in front of the printing machine a steam-chest covered with a woollen cloth, on which the stuff is applied as it passes under the cylinders. This arrangement, which may be very advantageous in certain circumstances, is not, however, without danger; it may happen, in fact, that too great quantities of steam may condense, and runnings or flowings be the consequence. The most rational method, and at the same time the surest, is, undoubtedly, to make them lie in a cool and damp place, and only to submit them to the printing in a room where the air has been raised to a pretty high temperature, and further completely saturated with moisture; there is then a condensation of the moisture on the surface of the stuff, which acts in these circumstances like a decanter filled with cold water when brought into a warm chamber. At the same time, before commencing the printing of a part of the goods, the printer should previously ascertain the quantity of moisture which one of the pieces requires to be properly damped, that he may approximately calculate the weight which the roller will have when they are wound upon it. Then, when they do not contain the required quantity of moisture, he has them conveyed from a cool place into one that is warm and very moist, and by unwinding them from one roller on another, he succeeds in saturating them with the required humidity.

PRINTING-ROOMS.—Having now explained the different machines employed in printing, the preparation of the colors to fit them for being applied to the goods by these machines, and the processes to which the goods are subjected to prepare them to receive the colors, something must be said of the arrangements and atmospheric condition of the printing-rooms before proceeding to describe the details of the different processes. It is evident from what has just been stated with reference to the damping of the goods, that much of the success of the printing will depend on the kind of atmosphere in which the operations are conducted, and on other things apparently subordinate, but really of vital importance.

The operation of printing with the hand-block is performed, as already stated, in long apartments or halls, which must, above all things, be perfectly lighted, and in which are placed opposite to one another two ranges of tables, each standing in front of a window. When the general arrangement of the place permits, it is more advanageous to have the light from above, but in a somewhat oblique direction.

The dimensions of the rooms for cylinder-printing are in proportion to the number of machines employed; and their position on the premises is sometimes determined by the moving power. Some printers have deemed it important that they should be at an isolated part of the establishment, and well lighted; but in these conditions PERSOZ remarks that they have always worked less successfully than those which are placed in the neighborhood of the dye-works, and in damp situations. Doubtless light is required, but it is necessary, above all, to guard, as far as possible, against the influence of atmospheric changes, and to have the power of saturating the air with moisture at pleasure, while keeping the temperature at a constant degree. It is desirable, indeed, that in every establishment there should be certain apartments naturally damp and others naturally dry, because, according to the kinds of work performed, the printer has more chances of succeeding when the atmosphere in which the operations are conducted is independent of the care of the workmen.

At the same time, it is for the intelligent printer to determine the exact degree of heat and moisture which it is proper to give to the air of the workshop for printing particular colors on particular stuffs. The temperature is regulated by the aid of thermometers, which are suspended at the upper and lower parts of the room, and thus make known its mean temperature. As regards the humidity, this may be determined by any kind of hygrometer. One of the simplest is a cotton string, traversing the whole length of the room, and this is found to possess all the required sensibility. In the middle of the cord is suspended an iron index, shaped like a needle and rather heavy, which rises and falls according to the degree of tension communicated to the cord by the humid medium around it. There are some printers who, to keep the air constantly super-saturated with moisture, either sprinkle the floor with water, or hang up packing-cloths charged with that liquid at the upper part of the workshop, or, placing a boiler in the middle of the room, cause water to boil in it so as to emit steam or vapor. Of all these methods the most advantageous is unquestionably that which consists in hanging up wet cloths, from which the air takes only as much water as it really requires; for the use of steam gives rise to condensations more or less prejudicial to the success of the operation.

The printer who neglected these precautions would not find, in printing a single lot of the same goods, three pieces which would be exactly identical. The principal point to which he must, above all, give his attention, is the relation which exists between the temperature of the cool and damp place in which the goods have been previously lying, and that of the warm air, equally saturated with moisture, of the printing-room. The more the difference between these temperatures, the greater will be the condensation, and it is his business to make the proportion such that the color shall fix itself perfectly on the stuff without flowing.

Even when all the precautions have been taken, it is still necessary, during the printing of the first piece, to make sure, by means of a white rag pressed against the engraved roller, whether any color remains in the cavities of the engraving, which never takes place but when the stuff has not sufficient humidity, or when the air of the chamber, not being sufficiently warm and moist, instead of giving up moisture to the goods, takes it from them, or lastly, when the color does not possess that degree of viscosity necessary for printing the pattern; and then, if the engraving does not empty itself completely, while at the same time the cause of this cannot be seen either in the temperature or moisture of the room or the goods, it becomes necessary to modify the color, and to give it the viscosity which is required to make it adhere completely to the stuff.

CALICO-PRINTING PROCESSES.—There are different styles of calico-printing, each requiring different methods of manipulation and peculiar processes. At the same time, though some of these styles are perfectly distinct from each other, the divisions established by different writers are somewhat arbitrary. The following enumeration seems to include all the *principles* of the methods adopted for printing every variety of pattern on white or colored grounds—sometimes applying them singly, and sometimes combining two or more in operating on the same goods:—

1. *Madder Style*, for soluble vegetal and animal coloring matters. In this style the thickened mordants are printed on the cloth, and the colors are afterwards brought up in the dye-bath, the tinctorial matter attaching itself in a durable manner only to those parts of the cloth on which the mordant, or mordants, have been applied. It is so called from being chiefly practised with madder, to which dyestuff, however, it is by no means limited in its application.

2. *Padding Style*, for mineral colors, in which the whole surface of the calico is first imbued with a mordant by padding, and different colored figures are afterwards raised by the topical application of other mordants, joined to the action of the dye-bath; or the cloth may be first printed with one of the two saline solutions, and be afterwards padded uniformly with the other.

3. *Topical Style*, for spirit and steam colors—so called because in this style the application of the colors is purely topical, and they are printed on the cloth along with the mordant, and afterwards fixed by exposing the cloth to steam. Some colors become attached to the cloth without a mordant, and without the process of steaming, but merely by drying with exposure to the air, in which case the colors are often brilliant, but fugitive.

4. *Resist* or *Reserve Style*, by which the white cloth is first impressed with figures in a thickened substance called the *resist*, or *resist paste*, which has the effect of preventing those portions of the cloth on which it is applied from acquiring color when afterwards subjected to a cold dye, as in the indigo vat; and this paste being afterwards dissolved off in a hot bath, the effect is produced of white or colored patterns on a blue or other colored ground.

5. *Discharge Style*, which consists in applying topically to the cloth, already dyed or mordanted, a substance called the *discharger*, which has the property of decomposing or dissolving out either the coloring matter or the mordant, and thus of producing on a colored ground white or bright figures, which may be afterwards printed different colors by grounding-in with the block.

6. *China-Blue* or *Pottery Style*, which is practised only with indigo, the pigment being printed on the

cloth in its insoluble state, and dissolved into the interior of the fibre by the successive application of lime and sulphate of iron, with exposure to the air.

7. There is another style called *mandarining*, by which a yellow or orange color is communicated to the goods by exposing them to the action of nitric acid. This peculiar style is practised only on silk and woollen stuffs, and will be explained in connection with the processes employed for these fabrics.

It is evident, from their mere definitions, that these different styles do not constitute perfectly distinct processes practised separately and independently on different goods. It is by the proper combination of two or more of them that the calico-printer produces his wonderful variety of coloring on the same goods. In the madder style, which is most extensively practised, and which may be regarded as affording the most comprehensive illustration of the principles of calico-printing, and its combination with the art of dyeing, the reader will at once recognize the exact process so graphically described by PLINY, as quoted at page 567. He will also perceive that the resist and discharge styles are only available in combination with other processes, either in printing or dyeing.

In proceeding to describe the distinguishing features, and some of the most prominent applications, of these different styles, the Editor desires it to be clearly understood that nothing but a mere outline is compatible with the limits and design of this work. To enter minutely into all the processes of an art which it would require a life-time to study, and which, to be fully treated, would occupy many volumes, is here simply impossible. The Editor will therefore confine himself chiefly to principles—to that part of the subject which belongs to chemical investigation, and to such an outline of the processes as seems to be essentially necessary for illustration alone. Ample receipts for producing different colors and mordants have already been given in that part of the present article which relates to dyeing; the different coloring substances have been explained, and those who desire to be minutely acquainted with the infinite variety of receipts for calico-printing compositions, must necessarily consult the voluminous works expressly devoted to that subject. It is the Editor's object in this article, while giving a general outline of the whole subject, to devote attention chiefly to those points which are not to be found discussed in any English works on calico-printing.

I. MADDER STYLE.—This is the most important and extensively practised style, being applicable not only to the dye-stuff from which it derives its name, but to nearly all organic coloring materials which are soluble in water, and capable of forming insoluble compounds with mordants—quercitron, logwood, weld, and cochineal, for example. In this style it is not the color but the mordant that is printed on the cloth, which is then subjected to the ordinary processes of dyeing, and the colors only make their appearance in the dye-beck. In this view, the actual printing is only a small part of the process; but as the success of the whole operation depends not less upon the subsequent dyeing and fixing than upon the printing itself, these must be considered an essential part of the business of the calico-printer, in this department at least, and therefore cannot be omitted in explaining the madder style. It is intended to discuss them indeed at some length, as affording a good opportunity of investigating the action of the dung and other agents which, although previously alluded to in treating of the processes for dyeing Turkey-red, have been chiefly reserved for the present department of the subject, to receive in this place the attention which their great importance demands.

1. *Printing-on the Mordants.*—The first process in the madder style is that of printing-on the thickened mordant, which is commonly done by the cylinder machine. The kind of mordant to be applied will, of course, depend on the color which it is desired to produce in the dye-beck; and different colors or shades of color will be so produced with the same dye by printing on different mordants, or mordants of the same kind but at different strengths. Thus, to produce different shades of red on the same piece from the same madder-beck, the cloth may be printed with red liquor of any density between 3° and 25° Twaddell. The thickener usually employed for red liquor is either flour or starch, or a mixture of equal parts of the two. The proportion of the thickening is varied according to the density of the mordant required, and the fullness or delicacy of the design; on the average, a pound and a half is used for a gallon of liquid. For a weak liquor, and for a delicate figure, either British gum, roasted starch, or gum-arabic is substituted for starch or flour.

An endless variety of tints, from red to chocolate, may be obtained from the same madder-beck by mixtures of the iron and aluminous mordants in different proportions, and all shades of lilac and purple, up to black, by different strengths of the iron liquor. Patterns in black and various shades of violet and purple may be imparted to cotton cloth in the madder style by printing iron liquor and red liquor as the mordants, and afterwards dyeing in a decoction of logwood. With an aluminous mordant a beautiful orange is obtained by a mixture of decoction of cochineal and decoction of quercitron.

It is needless to observe that when different mordants, or mordants of different strengths, are to be applied simultaneously to the same piece, each must be applied to the cloth by a different block or engraved roller, according as the hand-block, perrotine, or cylinder machine is employed.

By way of example, the following is selected as the composition of one of many mordants given by PERSOZ for a common madder red:—In ten gallons of boiling water dissolve thirty-three pounds of alum, and add twenty-eight pounds of acetate of lead and 2·8 pounds of soda in crystals; to each gallon of this mixture add three quarts decoction of campeachy at a strength of two ounces per quart, twelve ounces of chloride of zinc, and thicken with 2·5 pounds of pure starch.

Another is as follows:—In ten gallons of water dissolve 35·5 pounds alum, 24·5 pounds acetate of lead, 4·2 pounds crystallized carbonate of soda, and two pounds chloride of sodium; to each gallon of this composition add 4·5 pounds nitrate of zinc at 22° Twaddell;

thicken with 2·5 pounds of starch, and *sighten* with three ounces acetate of indigo.

2. *Drying and Ageing.*—If a cloth covered with a delicate pattern were left to dry at the natural temperature of the atmosphere or that of the room, on coming out of the printing machine, it is evident that, considering its state of humidity, and that of the mordant imprinted upon it, the impression would not preserve its regularity; the mordant would spread or run, and the fine and delicate lines of the pattern would in great part disappear, while the bold and massive parts would lose all their distinctness of outline. It is important, therefore, in regard to the execution alone, that the goods pass, immediately after being printed, into a warm medium, which, by seizing on the color at its surface, may arrest its movement on the cloth, and thus maintain all the original characters of the impression. It is needless to remark that this heat must be regulated both by the nature of the tinctorial matter and mordant, and the delicacy of the pattern. But it is not only to the realization of this effect that the part performed by the heat is confined; the application of this important agent is further made with a double object; the first, altogether chemical, partly to promote the decomposition of the acetates which are generally employed as mordants, and consequently, while tending to liberate the acetic acid, to fix the bases or subsalts on the stuff; partly to resist a too rapid oxidation of the iron of the mordant which it is desirable to realize only in the pores of the stuff, and not at its surface; the second, quite mechanical, to contribute to the juxtaposition of the mordant on the fibre. It is well known, in fact, that the vegetal fibre contracts by moistening, and, on the other hand, when it is saturated with humidity, it contains much less air; for two equal portions of calico, the one dry, the other moist, boiled with water over mercury, yielded volumes of air which were to each other as one to six; now if the vapor of water produces such a displacement, it is natural to think that the color, by being substituted for it, becomes more adherent to the fibre, since no air interposes between it and the surface of the fibre.

The goods, therefore, immediately after the imprinting of the mordant, are dried by being drawn either through the hot flue—see page 699—or over a series of thin sheet-iron boxes, heated by steam. A piece of calico, twenty-eight yards long, is usually drawn through the flue in about two minutes, and is thence conducted into the *ageing* room, where it is suspended, free from folds, for one or two days, according to the nature of the mordant and the temperature. The ageing room should not be very dry, or heated above the ordinary temperature, except during winter.

This exposure of the goods to an atmosphere, which ought to have a certain degree of moisture, has for its object to aid in fixing the mordants, by giving the acetic acid time to disengage itself from its combinations, and to the oxide time to combine with the stuff. When a ferrous salt has been printed, a rapid desiccation has the effect of securing it from the action of the air, from which the thickening preserves it by hardening. The exposure to the air of a stuff charged with this mordant is therefore indispensable, as well to complete the disengagement of the acetic acid, as to make it pass into the state of a ferric salt; but it is no longer so when one prints with ferric sulphate, and knows the means of fixing it. When the goods are covered with aluminate of potassa, exposure to moist air is still indispensable, for it is necessary that the carbonic acid of the air enter into contact with the mordant; and that by combining with the potassa, the alumina be set at liberty and combine with the stuff. As regards the mordants with a base of alumina, the ageing has chiefly for its object to expel the portion of acetic acid which remains on the cloth, and to increase the proportion of aluminia which combines with the fibre; nevertheless, when the desiccation of the stuff, on coming out from the rollers, has been carried far enough to effect a complete decomposition of the mordant, if the latter was of good quality, the cloth is quite as much saturated with it as after several days exposure; the only difference observed is, that the dyes are a little less brilliant, which proceeds without doubt from the circumstance that, by exposure to the moist air, the portion of tri-aluminic sulphate which is deposited by the heat, and has not been able to yield its base to the stuff with which it was not in contact, is redissolved in favor of the octahedral alum formed, and may thus subsidiarily come to cover the mordant with a slight coating which, formed in a slower manner, is always less dull. This last consideration ought particularly to fix the attention of the printer, for to find the conditions in which a mordant returns to the state of oxide or basic salt, as hard and transparent as possible, is to ensure the formation on the stuff of a lively and brilliant color, which could not be obtained by any other process.

With reference to the hot flue, or heated chambers, through which the goods pass before proceeding to the ageing room, PERSOZ remarks that from these warm chambers are disengaged torrents of acetic acid, which pass into the air and are lost; and he asks, would it not be reasonable to collect this acid and turn it to account? Would it not be possible, for example, to force out from these chambers the air which is saturated with it, by means of one or more ventilators, and either to make it traverse a certain quantity of hydrate of lime or chalk, to convert it into acetate of lime, or to bring it into contact with sheets of copper, to make verditer and acetate of copper, or, lastly, with sheets of lead, to make ceruse, with the intervention of carbonic acid.

3. *Dunging.*—As the precipitation of the mordant in the form of an insoluble sub-salt during the hanging or ageing of the goods is never complete, it becomes necessary to remove the unprecipitated mordant from the cloth before the dyeing, otherwise a portion of the mordant, instead of remaining on the pattern, would become distributed over the whole surface of the cloth when the pieces are put into the dye-beck, and thus would cause the adherence of the dye on those parts which had not been printed. The goods, therefore, after hanging in the ageing room for a sufficient time, are drawn through the dung-becks, or else through a strong solution of dung-substitute, or sometimes, for delicate colors, through a bran-bath, whereby a part of the undecomposed mordant is separated from the cloth,

and prevented from acting on the unprinted parts, by forming an insoluble compound with the dung or substitute; the thickening paste is removed; and the mordant remaining on the cloth is *more strongly fixed*, by uniting with some of the constituents of the dung or of its substitutes.

This operation is one of the most important and most delicate in the whole process, so much so that even if all the others should be performed with the most suitable materials, and in the best conditions, the printing would not the less be a failure, if the *dunging*, as this operation is termed, had not been performed with all the necessary care. But as dung is not the only substance employed, the operation is sometimes designated by the general name of *mordant-fixing;* and according as it is performed with one or other of the different materials employed, is termed *dung-fixing*, *substitute-fixing*, *bran-fixing*, *et cetera.* The fixing of the mordants, however, is not the only effect or object of the operation, and therefore it is considered better to adhere to the old name of *dunging*, whatever be the actual ingredients employed, using that word in the same sense as the expression *madder style* is applied to a series of operations, which, although most extensively practised with madder, apply equally to some other dyes.

It is not known exactly either at what period, or with what object, dung was first used in calico-printing; it is very probable that it was the use of sheep-dung in dyeing Turkey-red that suggested the idea of *animalizing* cotton, as it was then called, to render it more fit to attract the coloring matters; but whatever may have been the motive of its introduction into the print and dyeworks, it constituted a great step in advance, especially since an intelligent use has been made of it. It appears to have been employed in the Swiss printworks so early as about the middle of last century; it was only in 1790 that it began to be turned to account in France; but it was undoubtedly used at an earlier period in this country; although, till the latter part of the last century, its application was not, as in the present day, a general practice, based upon scientific principles.

According to an analysis by M. Penot, cow-dung contains the following ingredients:—

	Centesimally.
Woody fibre,	26·39
Albumen,	0·63
Chlorophyl,	0·28
A sweet substance,	0·93
A bitter matter,	0·74
Chloride of sodium,	0·08
Sulphate of potassa,	0·05
Sulphate of lime,	0·25
Carbonate of lime,	0·24
Phosphate of lime,	0·46
Carbonate of iron,	0·09
Silica,	0·14
Water,	69·58
Loss,	0·14
	100·00

M. Morin's analysis assigns to it the following composition:—

	Centesimally.
Water,	70·00
Bubulin,	1·50
Biliary matter,	0·50
Green resin and fatty acid—butyric, oleic, and margaric acids,	1·52
Albumen,	0·40
Fibrous matter,	24·08
Saline matters, carbonate, phosphate, chloride, silica, ammonia, and iron,	2·00
	100·00

Several attempts were made at different times to introduce an efficient substitute for cow-dung; and M. Haussmann, who studied the action of various substances with this view—that of chalk, of the bicarbonates of potassa and soda, and of soap—showed that in the heat these last substances are not fitted to replace it, seeing that by their base they attack the alumina, and that mordanted stuffs, treated with soap and bicarbonate, became unfit to attract the coloring matter of a dye-bath.

It is only within the last few years that the dung emulsion has been to some extent superseded, in many well-conducted print-works, by a solution of a mixture of phosphate of soda and phosphate of lime, known by the name of *dung-substitute*, or simply *substitute*, for the preparation of which a patent was obtained by Mr. Mercer, Mr. Prince, of Lowell, Masachusetts, and Mr. Blyth. This substance is prepared by mixing sulphuric acid with bone-ash, which consists chiefly of phosphate of lime; the acid not being applied in sufficient quantity to decompose the phosphate of lime entirely, but to produce an acid phosphate, or a solution of the phosphate in free phosphoric acid. Carbonate of soda is then added to neutralize the free acid completely, and the mixture is evaporated until the residuary mass become almost dry. When the concrete thus obtained is mixed with water, it affords a solution of phosphate of soda containing some phosphate of lime; a white mud remains undissolved, consisting of sulphate, carbonate, and a little phosphate of lime, which should be carefully stirred up when the liquid is about to be used. But this preparation is not of itself an efficient substitute for all the important constituents of the dung. To supply an emollient and detergent substance in the place of the albuminous matter of the latter, it is found necessary to mix with the above liquid a solution of glue, or some other form of gelatine. The material employed for this purpose in most print works is a solution of bone-size, called *cleansing-liquor*, which is made by boiling bones in water for nearly a week, separating the fat which rises to the surface of the liquid, and evaporating the aqueous solution of gelatine until it attains a density of about 36° Twaddell. The method of applying this solution will be described afterwards.

Sometimes, on the Continent, a bath of sal-ammoniac, or of bicarbonate of soda, is substituted for the dung-emulsion; the former, in fixing an aluminous mordant, seeing that the potassa seizes on the acid, and the alumina set at liberty, not being able to dissolve by the action of the ammonia, remains on the stuff; the second, when one wishes to fix, in the cold, mordants with bases of acetate of alumina; lastly, but only when the mordant has a base of acetate of iron, ammoniacal gas is applied, which seizes on the acetic acid and sets at liberty the base imprinted on the stuff, with which it remains united in an intimate manner. An important precaution to be taken in this case to obtain the effect desired, is only to expose the printed goods to the action of this gas when the color has a certain degree of humidity; for, if it be too dry, the gum, acting as a varnish, preserves the mordant from the reach of the ammonia, and renders useless all the expenditure of manual labor, of time, and material. It is, doubtless, from not having taken this peculiarity into account, that printers have misunderstood the influence of the action of this gas in these circumstances.

The action of bran and other substances used in particular cases instead of dung, will constitute the subject of future consideration. In the meantime the details of the process will be stated, on the understanding that dung itself is the substance employed.

To explain more clearly, however, the object proposed to be effected by the operation of dunging, it may be desirable to state briefly in the first place the nature of the different substances which are found, after the ageing, on a stuff which has been printed with one or more mordants. Assuming for example that the pattern is to consist of six colors or shades; in that case six mordants have been printed—say, three with an iron base to form with the madder a lilac, a violet, or a black; two with an aluminous base, to produce a light red and a dark red; lastly, the sixth formed of a mixture of these two bases, to furnish a puce. This example is merely selected to show the variety of pattern of which the madder style admits with a limited number of ingredients; and in this case, after the printing and ageing, the following substances will be found on the goods:—1. The thickening which has been used, and which, according to its nature, is more or less soluble in water. 2. The false color, called the sightening, which may have been required in the mordant to enable the printer to follow his work, and which may consist of charcoal, indigo, infusions of Campeachy, Brazil wood, or other coloring substances, sometimes capable of removal only by chemical displacement. 3. Alumina, or hydrated oxide of iron, according to the kind of mordant. 4. Sulphate of alumina—red mordants—or a certain quantity of basic acetate—mordants of iron. 5. Cubic alum, which is re-formed by the reaction of a portion of octahedral alum on the alumina or the tribasic sulphate, which, not being in immediate contact with the stuff, is not combined with it—mordants of alumina. 6. Variable quantities of anhydrous cubic alum, the formation of which depends on the proportions of steam introduced during the desiccation of the mordants—mordants of alumina. 7. Octahedral alum in so much greater proportion as the alum employed was more acid and less thoroughly saturated by an acetate—mordants of alumina. 8. A quantity of mordant of alumina, or mordant of iron undecomposed, when the goods have not been exposed to a sufficiently high temperature after their printing, and especially when they have not been heated in a moist atmosphere.

If one could ever be sure of having fixed by the impression on the stuff, the quantity of mordant necessary to obtain the desired shade, and that, moreover, the excess of the mordant could be taken off by the water without being shifted on the white parts, it would be sufficient to wash the cloth in appropriate machines till the gum and the excess of mordant had entirely disappeared; but unfortunately this is not the case: goods printed at the same time and with the same mordants often exhibit places more or less charged with color, according as, during their circulation in the drying apparatus, certain parts have been more acted on either by a current of moist air, which has there fixed a greater quantity of mordant, or of dry air which has produced a contrary effect, and hence it becomes necessary to get rid of this inequality of tone or of shade, by forcing the mordant to combine with the stuff in the parts on which it has not been fixed. There are likewise portions of mordants which, not being in immediate contact with the stuff, and consequently not in desirable conditions for adhering to it, might get detached and deposited on the reserved parts; now, it is of great importance to prevent the blemishes which would result to the dyeing from this displacement. On the other hand, the mordants are always accompanied with variable proportions of acid, which it is indispensable to saturate to prevent their action on the parts which are fixed. Lastly, it is always required to get rid of the quantities of mordant which, not being intimately combined with the stuff, would get detached, either during or after the operations of the dyeing, and while causing a pure loss in the consumption of coloring matter, would nevertheless produce only shades more or less scratchy, due to the less colored parts, which their disappearance would leave exposed. To attain these results recourse is had to *chemical* and *mechanical* operations.

The former, which consist in passing the goods into a bath of dung or dung-substitute, heated to a suitable temperature, have for their object:—1. To set up the entire combination of the aluminous and iron subsalts, which are formed by seizing on the acid which the desiccation has not expelled. 2. To dissolve and take away from the stuff the greater part of the substances which have served to thicken and to color the mordant. 3. To separate from the stuff the parts of the mordant which are not combined with it, while preventing at the same time these parts from spreading over the surface, adhering to it, and attracting the dye.

The second operations to which the goods are subjected, and which are purely mechanical, are simply washings or scourings, perfectly similar to those which have been described in treating of bleaching, and have for their object to aid in the expulsion, not only of the soluble parts which could not be extracted from the stuff by a simple immersion in water, but further of those which are insoluble and which, not forming an essential part of the fabric itself, require to be detached from it. As these operations have been explained at length, it will be sufficient to have indicated them at present.

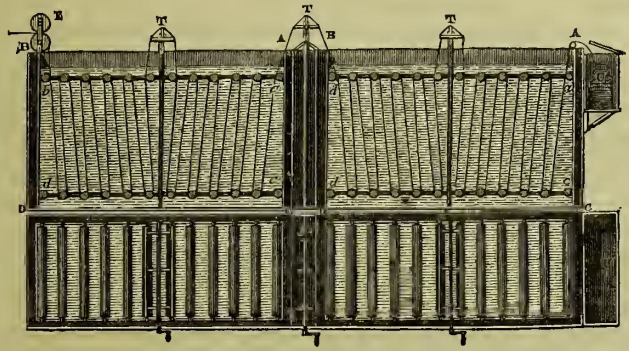
In now proceeding to describe the chemical part of the process, it will be assumed in the first place as has been stated, that cow dung is the substance employed; this recrement being found to act with effect whatever be the nature of the mordant, both because it contains alkaline and earthy phosphates and carbonates, which have the effect of determining a double decomposition on the uncombined portion of the mordant, and of precipitating it in the state of phosphate, *and also* because it contains fixed organic matters, among others albumen, which by reacting on the saline solutions form with the bases combinations so intimate that the goods cease to have any action upon them.

Dunging is usually performed in two operations and acewo different vats, whence the distinction into dunging by the cistern or square vat, and circular dunging by the wince in the common dye-beck.

The cistern or square vat is a large wooden trough of the capacity of about eight hundred to one thousand gallons, and heated by steam. In the interior of this trough are arranged movable cylinders, intended to keep in steady motion, and in a state of tension, the goods passed into the bath. These cylinders are placed parallel to each other in two rows; sometimes one row or series is placed below and the other above, so that in this case the goods sink and rise alternately in the bath; sometimes the cylinders are placed on opposite sides, and the movement of the cloth then proceeds through the whole depth of the vat, following a direction parallel to the surface of the liquor. These cylinders are either fixed to the interior sides of the vat itself, or, which is more convenient, especially for making repairs, mounted in a wooden or iron frame, which is let down into the vat and taken out at pleasure.

Fig. 390 represents the first of these arrangements, or what may be termed the vertical system; only, instead of a single vat, there are two together, ABCD, ABCD; these two vats often form only one, divided by a partition. The two troughs or compartments have for their special object to allow the printer to add in one of them matters which serve to complete or promote the dunging; thus, there are mordanted goods, as those on which discharges have been printed, which are strongly charged with acid; in that case, to saturate this acid, it is customary on the Continent to add a large proportion of chalk to the first liquor. On coming out of the first cistern, the goods pass into a bath of fresh dung; at one of the extremities of the cistern is another trough fitted with a lid, in which the goods to be dunged are enclosed, since it is indispensable to preserve them from the drops of water which might reach them, and cause so many spots upon them. At the opposite end of the same cistern, if there be only one, or of the second, if there be two, are placed two traction cylinders, E, B, which have for their object to draw the stuff and assist its movement. At the intermediate points are sometimes placed pulley-rollers, T, T, T, which, while attaining the same end, permit likewise to judge of the state of the goods during their passage; in other words, to see if they are properly stretched, if no folds have been contracted, or any rents made.

Fig. 390.



The movement of the machine is very simple: two cords are passed between each cylinder in the direction to be given to the movement, and these are attached to the end of the pieces, which are fastened together to the number of thirty or forty; then it is only necessary to turn the traction cylinders to cause these pieces to emerge from the trough, U, to dip into the dung-bath, which must have been previously brought to a given temperature, to sink, rise, and sink again in passing alternately under the rollers, *c d*, *c d*, and over the rollers, *a b*, *a b*, and to rise at last to pass between the two cylinders from which they are conducted to where they are to undergo the operations of scouring or rinsing.

Fig. 391.

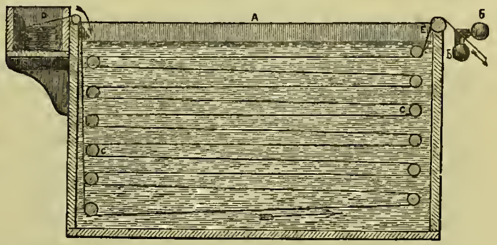


Fig. 391 represents the second arrangement above mentioned; A is a vat about ten to twelve feet in length, five or six feet in depth, and about the same breadth. On emerging from the trough D, the goods sink into the bath, till, arriving at the bottom, they rise again, following, in their circulation on the rollers, *c*, *c*, a direction almost horizontal, and arrive at last between the two traction rollers at E. On quitting these rollers, they pass at a suitable distance between two copper cylinders, *b*, *b*, pierced in the direction of their width with a row of holes through which jets of water, under a very strong pressure, are thrown upon the goods, and exercise their action in a contrary direction to that of the movement of the cloth. This rinsing of the goods on coming out of the vat greatly facilitates the operations of scouring.

When the dung-bath cannot be conveniently heated by steam, the operation is performed on the open fire in a copper boiler, in which the goods are made to circulate by means of a frame of rollers.

The goods which have undergone this first operation in the square vat are rinsed and then scoured with care, either by putting them into the dash-wheel, or by one or other of the methods described in the article on Bleaching; and these mechanical operations being finished, the second part of the dunging is proceeded with. For this purpose the pieces are connected two by two in each of the compartments of the dye-beck, described under the next process, so as to form an endless string of goods; and as this beck is divided into several compartments, there will be a proportional number of pieces in it at one time. Then, in consequence of the movement communicated to the wince at the top of the beck, the goods circulate in the bath, and the friction which takes place detaches the parts of the mordant which are not perfectly adherent to them. The more rapidly the goods circulate in this bath without tearing, the more thoroughly will they be cleaned, since in this case the particles of water drawn in come into collision with each other, and falling back determine a depression in the pores of the stuff, which empty themselves and thus get clear of the foreign matters which they contain.

On coming out of this second and last dung-bath, the goods, cleaned and scoured as after the first dunging, are ready for dyeing.

Having thus explained in a general manner the operations of dunging, it remains to give some details which are required to render the account of them complete, and to insure success.

The dung-bath into which the goods are passed, extended to their full width, in the square cistern, is usually composed of six to eight hundred gallons of water, and one hundred and fifty to one hundred and seventy pounds of dung. In France it is usual to add from three to sixty pounds of chalk, according to the nature of the dung and the quantity of acid which exists on the cloth; but in this country it is unusual to make any such addition to the dung, except in cases where the cloth contains a notable amount of free acid or acidulous salt.

As the composition of this bath goes on constantly weakening in proportion as the goods are made to circulate through it, care is taken to keep it at the proper degree of strength by adding to it from time to time a certain quantity of dung, or other substances required, according to the nature of the mordants employed. Something may be learned from the continental practice; and what must be avoided above all is, that the bath do not contract an acid reaction, which would carry off the parts of the mordant that are fixed on the stuff.

The dung-bath in which the goods are winced in the second operation is usually a little weaker. In dealing with the first or second bath, care must be taken to graduate its force according to the mordants which are made use of; otherwise a risk would be incurred of having the latter much weakened by the dissolving action which would be exerted upon them by the constituents of the dung—albumen, phosphate of soda. It is for this reason that when it is the object to obtain parcels of goods of exactly the same shade, they are never passed into a fresh bath, which would always render much weaker the tint of those which might be first dipped in it.

The choice of the dung is not a matter of indifference, for its nature or quality may exercise a certain influence upon the success of the operation. Printers have remarked that the dung of cows fed on dry fodder is always infinitely preferable to that of cows kept on green food. PERSOZ remarks that this inferiority is more especially apparent when the food of these animals consists chiefly of beet-root, so much used on the Continent. He says it has happened in several French printing establishments, that lots of goods have proved entire failures, because the dung employed proceeded from cows fed in great part on that root, the mordants being scratchy, and the shades without lustre. This difference may be explained by the small quantity of phosphate which the dung from that source is known to contain, and also by the very small quantity of fatty acids which exist in it. The same phenomena are produced when the cows have diarrhœa, and the aliment of these animals passes through the digestive apparatus without being completely digested, for then the dung contains much stuff strongly acid, which performs a part exactly contrary to what is required.

The temperature to which the bath should be heated varies from 112° to the boiling point, according to the styles of printing, the kind of mordants or rather the nature of the coloring matters which they are required to saturate, the intensity of the shades desired, and lastly the nature of the thickenings. With reference to this last point, it is evident indeed that mordants thickened with starch require, in order to be softened and disengaged from this glutinous substance, a much higher temperature than those which have been thickened with gum-senegal, with roasted starch, or any other body of great solubility in cold water, and consequently still more in warm water. A long experience has proved, moreover, that mordants intended to fix such coloring matters as those of quercitron, weld, and cochineal, seize upon these substances the better in proportion as the dunging is performed at a lower temperature, and as it is, consequently, less thoroughly saturated. It is thus that if a piece of cloth be padded or printed with mordant of alumina, and after dividing it into four parts, one of them be dipped in water, another in a dung-bath heated to 90° Fahr., the third in the same bath raised to 140°, and lastly the fourth in the same at the boiling point,—then, when all the samples have been cleaned with the same care, and after being dried are printed with a solution of thickened citric acid, it will be seen that this latter substance, which exercises its full action on the sample that was only passed into the water, has only a very slight action on the mordant dunged at 90°, a still weaker on that which was heated to 140°, and that it is almost without any effect on the sample dunged at the boiling point. Hence it is not surprising that printers dung only at a low temperature the mordants intended to be dyed in quercitron, weld, or cochineal, and that often, even for this kind, they cause the goods to be passed into a water to which has been added a small quantity of chalk.

The injurious consequences of too high a temperature of a dung-bath may proceed from another cause. Indeed, if, as theory indicates, the albumen of the dung masks the uncombined mordant which gets detached from the stuff, and renders it unfit to contract any new combination with the fabric, it is obvious that a too strong heat may annul more or less the effects of the dung by immediately precipitating the albumen by the coagulation which that substance always undergoes at about 160°.

These negative effects do not make themselves less felt when a little bicarbonate of potassa or soda has been added to the dung-bath, since these salts being decomposed by the heat, pass into the state of carbonates, and then react unfavorably on the mordants, which they always attack more or less, especially the mordants of alumina; moreover, HAUSSMANN, and other printers, who were not decided upon the conditions of temperature at which it is possible to employ them, came to the conclusion to reject these substances.

The duration of the immersion, or, in dunging with the cistern, the speed or rate of movement to be given to the goods, demands also serious attention. When the cistern or square vat is used, the speed communicated to the traction cylinder should be such that a piece will take from four to six minutes to pass through the bath. When dunged by wincing in the dye-beck, the temperature of the bath and the duration of the dunging for the principal styles should be nearly as follows:—

	Temperature of the bath.	Duration of immersion.
White grounds, rose and violet,..	140° or 150°,..	10 to 15 min.
——— black and red,...	150° or 160°,..	15 to 20 —
When the patterns are charged and padded with strong mordants,..	170°,	..20 to 30 —
Mordants for half-grounds, re-entered after the dyeing,.........	140°,	..15 —

Sometimes the wincing or circular dunging is performed at a more elevated temperature, and the bath is brought to ebullition; but this practice, which may offer no disadvantage for certain kinds, presents on the contrary great disadvantages when iron and aluminous mordants have been simultaneously deposited on the stuff; for then it is not uncommon to see the ferruginous mordant carry itself over the red, however little it may be masked at the very moment of its being detached.

The manner of immersing, or of passing the goods padded or printed with mordant into the dung-bath, is also not without a great influence on the success of the operation; it is proper, therefore, to be very careful on this point. Experience proves that it ought to be done with the greatest possible rapidity and regularity; this may be concluded at least from the following experiments related by M. DANIEL KŒCHLIN in his memoir on dunging:—

A stuff impregnated with a strong mordant was divided into three parts, and, shortly after desiccation, they were put into the dung-bath, proceeding as follows:—the first, well stretched on a pole, was immersed suddenly, and left a minute in the bath stirring it about; the second, also stretched, was dipped slowly, so that the upper part was half a minute after the lower in being immersed in the water; the third was rolled together, dipped, and withdrawn immediately on being wetted. These three samples were scoured and dyed. The first presented a strong and full tint, the second a poor and scratchy color, the third was only slightly dyed at some parts, and exhibited a great number of blank spots.

To this fact we shall add two which are very simple and leave no doubt on the subject. Let water be applied with a pencil on any points near the end of the piece, so as not to injure its value, and it will be seen that each of the parts so touched will become a spot; or, again, let the movement of a piece through the bath be interrupted, and let the point be remarked where it reaches the level of the bath as it passes into it—a mark will be observed after the dyeing, which will correspond to that point, and will extend over the entire width of the stuff. To explain such a phenomenon, it is necessary only to understand thoroughly the object of the first operation in the dunging, which is to saturate the mordant, or to effect, upon those parts of it not disintegrated, a double decomposition which renders it unfit to combine with the goods. It will hence be understood that if a drop of water falls on the stuff, or if the progress of the piece be interrupted, the liquid penetrates in virtue of the capillary action into the pores of the stuff, and draws in, in its movement, the unfixed portions of the mordants which, by spreading on the blank parts, give them the property of attracting the coloring matters of the dye-bath. Besides this disadvantage, which is sufficiently serious in itself from the spots or blemishes it produces, the lines of the pattern, not having equal force at all points, diminish the distinctness of the impression. For these reasons it is important that the colors be of great permeability to water, and that, at the instant when the liquid has access into the pores of the stuff which is covered with it, a double decomposition be effected, the result of which is a gelatinous precipitate, which keeps the color at the very point where it has been deposited, and thus gives it the time necessary for its incorporation with the fibre, while favoring the separation of the thickening by the operations of the scouring. From these observations it will be perceived that it is essential for the thickener not to be too slow in imbibing water; otherwise, the ungumming taking place only during the scouring operations, folding-stains more or less prejudicial would be the inevitable consequence.

Even when care is taken to keep up the strength of a dung-bath, the number of pieces which can be passed through it is not unlimited; for a period arrives when the liquid, being supersaturated with oxides, would necessarily compromise the success of the operation by depositing them on the stuff.

Struck with the important part which cow-dung performs in the fixation of mordants, several chemists have endeavored to establish a theory of its operation, which is, on the whole, somewhat abstruse. MORIN attributed all the peculiar properties of the dung to what he termed the *bubulin*, which he discovered in it, and which he considered to be the principal agent in precipitating the metallic solutions. PENOT, who took a different view, tried to prove that the soluble and insoluble parts of the dung are capable of neutralizing and completely precipitating the oxides, which serve as bases to the mordants. CAMILLE KŒCHLIN, guided by other considerations, attributed the principal effects of the dung to the action which the fixed organic matters exert on the metallic solutions, and this scientific printer was thus led to demonstrate, contrary to the opinion both of MORIN and PENOT, that the bases of the mordants which are found in the dung-bath may exist there in solution and in variable quantity, according to the quality and the respective proportions of these mordants and of the fixed organic matters. He found, in fact, in the insoluble part of this bath, as well as in the soluble part, strong proportions of oxide, but, what is rather remarkable is this, that whilst the former or insoluble part contains quantities of iron and alumina sensibly equal, *no trace of iron appears in the soluble part.*

The plan of this work does not permit of reporting here the numerous experiments performed by CAMILLE KŒCHLIN, to ascertain the precise part performed by the constituents of the dung, and to determine the power which the latter possesses of saturating and masking the metallic oxides; the substance of his conclusions, however, may be stated as follows:—It is known that the first portions of the acetates of alumina and iron, dissolved out from the goods, will remain in solution till the collective affinities of each of these mordants are equal to the point of saturation of the soluble condition of one of them; that then the combination of the iron mordant with albumen will begin to precipitate, whilst that of alumina will remain in constant solution till that point at which its quantity, joined to that of the acetate of iron, forms a *whole* sufficient for the neutral combination of the dung. Arrived at this point, the latter will be no longer able to continue its action, and, unless reinforced by the addition of a fresh allowance, all the portions of mordant lost by the goods would be again deposited on the unprinted surface. Such is the theory propounded by PENOT, but of which, at the same time, he attributes the principal merit to PERSOZ.

Based on experiment, says the latter chemist, this theory is placed beyond doubt, but it will admit of further elucidation. It is thus that, having regard to the phosphates which the dung contains, the saturating power with which it is endowed, both in the insoluble and soluble parts, is explained to a certain extent, since experiments prove that the phosphate of lime, which is insoluble, is able of itself to effect the saturation of a mordant deposited on a stuff: perhaps, also, the printer would do well to give the preference to this phosphate over chalk for saturating the acid mordants; then, whatever excess there might be of this substance, his printings would never be injured, as often happens during the dunging in such cases, by the great quantity of chalk which must be used, and the large proportion of acetate of lime which is formed, and which, by acting as bases, more or less degrade the aluminous mordants. Moreover, by studying the composition of the dung and of the mordants which have passed into a bath of this substance, appreciable quantities of fatty acids have been detected, the presence of which cannot be without effect on the dyeing. Lastly, regarding the dunging in another point of view, one may even consider it as a true dyeing performed at the expense of the coloring matter of the dung, which maintains the oxide in that isomeric modification in which it dyes, and is then expelled by a stronger tinctorial substance, in virtue of a true displacement, when the period arrives for passing the mordanted goods into a dye-bath.

Fixing with Bran.—Formerly, bran was frequently employed instead of the dung emulsion, especially to obtain delicate shades, which the coloring matter of the dung more or less tarnishes—tender yellow, rose, and lilac, cochineal, or lively colors composed either of two coloring matters or of two mordants; gold-color, cinnamon, chocolate, carmelite, capuchin, chestnut, yolk-of-egg, orange, olive, purple, archil; or, lastly, colors for which the mordants are re-entered into grounds already dyed.

To compose the bran-bath, it is usual to mix with six hundred and fifty gallons of water about a bushel and a half of bran, which has been previously made to boil in a portion of the liquid. The operation of passing the goods through this bath is most frequently performed in the circular way in the dye-beck, but it would be more advantageous to perform it in the square vat, to avoid the running or *flowing* of the mordants. The duration of the bath is from eleven to fifteen minutes; then they are rinsed several times successively in the usual apparatus.

The action of the bran in this operation is not difficult to explain: composed essentially of alkaline and earthy phosphates, with a pretty large proportion of alumina and of gluten, it combines all the necessary qualities, as well for saturating or precipitating a mordant as for resisting the tendency of those portions which, not being intimately united to the cloth, might get detached from it, to contract a more intimate combination with the non-mordanted surfaces.

PERSOZ found, by direct experiments on bran-baths exhausted by mordanted goods, that they contained, according to the nature of the mordants, more or less considerable proportions of alumina and oxides of iron, in intimate combination with the albumen, and especially with the phosphoric acid; the bran acts, therefore, quite as much by the phosphates as by the albuminous matters which it contains. The bran, moreover, while yielding, like the dung, a certain quantity of fat on analysis, is distinguished from the dung by an acid reaction, which, however, can always be neutralized when requisite; but this neutralization is necessary only in a small number of cases.

In the present day, bran is used more particularly for brightening the colors, and bringing back to their original purity the parts of the stuff which have not been covered by mordants, but the white of which has been soiled in the dyeing. The process of brightening with bran will be explained afterwards.

Dunging with Chemical Substitutes.—The method of preparing the dung substitute in common use, consisting of solution of phosphate of soda and phosphate of lime, has been already described. The following detailed account of the mode of applying this solution to mordanted goods was communicated to Mr. PARNEL by Mr. JOHN MERCER, one of the patentees. It refers to cases in which dung is entirely dispensed with, and in which the mordant has been applied to the cloth topically, as in the madder style.

A normal solution of substitute, called *substitute liquor*, is first made by dissolving the substitute in warm water, at the rate of two pounds to the gallon. Six gallons of this liquor and two gallons of the solution of bone-size, called *cleansing liquor*—see page 711—are introduced into the cistern or square vat, which is then filled with hot water, and the pieces of cloth are passed through, by means of the rollers, at the rate of thirty yards per minute. The common dung cistern is employed in this operation, and should be capable of holding not less than six hundred gallons, with a series of rollers sufficient in number to allow the immersion of at least fifteen yards of cloth at the same time. The temperature of the solution may be the same, in general, as that of the bath in the common dunging process; for madder purples and pale reds, it should never exceed 140°, but for madder blacks and full reds it may be a little higher. This cistern requires to be frequently renewed by the addition of fresh quantities both of substitute and cleansing liquor. A gallon of the former and a quart of the latter may be added for every thirty or fifty pieces, according to the *heaviness* of the work, or the quantity and strength of the mordant on the cloth.

When removed from the first cistern, the pieces are well washed in water, after which they are winced in the weaker solution of substitute. The latter may be contained in a wince-pit or cistern, capable of holding about three hundred gallons, with which quantity of hot water there should be mixed two quarts of substitute liquor and one quart of cleansing liquor. In this liquid twenty-eight or thirty pieces are winced for twenty or twenty-five minutes, at a temperature about 10° lower than the solution first applied. The second cistern requires to be renewed by the addition of two pints of substitute liquor and one pint of cleansing liquor for every twenty-eight pieces. Both this and the first cistern should be fresh charged every morning, and emptied at night.

The only remaining operation to which the pieces are subjected, previous to being dyed, is a thorough washing in water; and if the work is heavy, they should also be passed between the squeezing rollers, and again washed.

Where the use of dung is only partially superseded by that of the substitute, the pieces are sometimes first passed through the common dung emulsion, and afterwards winced in a weak solution of substitute, mixed with cleansing liquor or glue: or the pieces may be first passed in the ordinary manner through a mixture of half the usual quantity of dung, with half the above proportions of substitute liquor and cleansing liquor, and be afterwards winced in a solution of substitute of the same strength as the second, applied as above without any dung. For madder reds, the mixture of dung and substitute seems to be more advantageous than substitute or dung alone; but for madder purples and black, a preference is given to the use of the substitute only.

The exposure to dung or substitute of cloths mordanted with alumina, should not be prolonged a sufficient time to allow of the union of the alumina with a full proportion of phosphoric acid, for coloring matters do not readily displace phosphoric acid from such a combination. The phosphate of iron, on the contrary, is easily decomposed by tinctorial matters.

Persoz remarks, that the use of this salt, or substitute, gave rise in France to some observations which may be interesting to the English printer. It was found, for example, that with the same mordants it produces hues much deeper than the dung, and this result, he states, has nothing extraordinary in it to those who understand the part performed by the phosphates. These, in fact, fix by a double decomposition the undecomposed mordant, which then becomes added to that which adheres to the stuff by the mere effect of the exposure of the goods in the hot flue, and gives a stronger tint than that which is obtained by the ordinary dunging; but it is sufficient, in order to realize the tints which one has an interest in producing, to reduce the strength of the mordant that is made use of, and to proportion it to that of the dunging salt. Some printers, while admitting its use for the mordants of iron, reject it for mordants with an aluminous base; but if it does not give the desired results when it is employed at too high a temperature, or when it contains too much phosphate of soda, it is sufficient, in the former case, to lower the temperature of the bath: in the second, to reduce the proportion of phosphate of soda. Besides, one can always increase the proportion of phosphate of lime without fear of accident.

Another double salt employed as a substitute for dung, instead of the phosphate, is the *arseniate of lime and potassa*, which is prepared in the same manner as the phosphate bath, by adding to six hundred gallons of water about twenty pounds of bi-arseniate of potassa, previously saturated with the necessary quantity of chalk, or with any other alkaline base; nevertheless, it is found, from long experience, that it is always best to employ the chalk. The composition of the bath may then be considered as consisting of arseniate of lime, which dissolves with difficulty, and arseniate of potassa, which is very soluble. It is needless to say, that in using this salt, as in ordinary dunging, or in fixing with the phosphate solution, the strength of the bath must be kept up by a suitable addition of the double arseniate, after the immersion of a certain number of pieces. The efficacy of this mixture is not difficult to understand. The arseniate of potassa, by penetrating the color, transforms the aluminous and ferruginous salts into insoluble arseniates, which remain adherent to the stuff, if they are in immediate contact with it, or detach themselves from it in the contrary case, and are then attracted by the undissolved part of the arseniate of lime, which performs the part of an absorbent body. This last, which is scarcely soluble, performs the same functions as the arseniate of potassa, although with infinitely less energy, and acts, besides, by fixing and neutralizing the excess of acid of the mordant.

It has been remarked, that these chemical substitutes for dung are only employed, with the addition of gelatine or cleansing liquor, for the purpose of preserving the blank parts of the stuff. Persoz maintains, as the result of different experiments made by himself, that this addition is not indispensable. He remarks, that when the strength of the mordants has been duly regulated, and the bath contains the necessary quantity of salt to determine the double decomposition, without attacking the oxide previously fixed, one is pretty sure to attain the end proposed in this operation; namely, to be able to dispense with scouring between the first and second application of the dung salt.

The reader will more clearly comprehend the influence of the phosphates and arseniates in dunging, if he reflects that the nitrates, the sulphates, the chlorides of alumina and iron, which give none of their bases to the linen and cotton stuffs on which they are applied, when merely passed into water, yield them up, on the contrary, to these stuffs when they are dipped in a bath holding in solution, and in suspension, the substitutes for dung above mentioned. These salts fix, therefore, saline compounds which by themselves do not combine with the stuff, and further prevent their *flowing* on the parts of the stuff to be reserved. Their effect, moreover, sufficiently justifies the part which has been assigned to the phosphates contained in the dung.

Gaseous ammonia has sometimes been used for the same purpose, and PERSOZ states that he saw it so applied in the establishment of Wesserling, where it was first brought into use as an occasional substitute for dunging by M. HENRI SCHLUMBERGER. It is specially appropriated to the fixing of violet mordants, for it has been remarked that the mordants of alumina exposed to the ammoniacal gas furnish brick tints.

In the application of the volatile alkali, the goods, on coming out from the printing machine, are exposed for three days to hot and moist air, as well to promote the oxidation of the mordants as to give to the color time to liquefy, and to penetrate into the pores of the stuff; they are then made to circulate in a chimney or flue, close at the top, and in which a current of ammoniacal gas is kept up to repair the loss resulting from the movement of the goods, which always imbibe a portion of it with the air, and that arising from the saturation of the acid parts of the mordant.

It appears indispensable for this operation to render the mordant as hygrometric as possible, so that an exposure of some days in the ammonia chamber may suffice to make it take up the quantity of ammonia necessary for the saturation of the acid and the precipitation of the oxide, which, when super-oxidized, loses the property of dissolving during the ulterior operations. If the color is of a drying nature, it acts in some sort the part of a reserve upon the goods, the latter alone being then charged with humidity and attracting the ammonia, so that, on passing them into the bath to remove the thickening, it will be seen that pretty strong proportions of the iron oxides dissolve in virtue of the ammonia, which, in the gaseous state, has not previously decomposed the salts. These observations explain how goods unequally desiccated in drying chambers which are not properly arranged, attract the ammoniacal gas unequally.

The *alkaline bicarbonates* are also occasionally employed to fix the mordants, and though it appears probable that one or the other of these salts may be used indifferently, nevertheless the bicarbonate of soda is that to which it is convenient to give the preference in point of economy. The solution of this salt may be made in the cistern itself in which the operation is conducted. This consists in immersing in the cold the printed goods in the cistern filled with water long enough to moisten the color, and to effect the precipitation of the base on the stuff, which has then only to be washed in order to detach the portions of oxide which do not adhere. This method of fixing is sometimes employed with advantage, especially for grounds which would be injuriously colored by the use of dung.

4. *Dyeing.*—When the goods have been submitted to the operations of dunging, either employing dung itself or one or other of the substitutes above mentioned, they are well washed, and are then ready to be exposed to the dyeing liquor. In describing this part of the process, it will be assumed that the coloring matter of madder, from which the style under consideration derives its name, is the dye employed; for although, as already stated, the same process applies to quercitron, cochineal, and some other dyes, these are managed in the same general manner, and are only distinguished by some peculiarities.

If the operations of the dyer, properly so called, were applicable in all points to the calico-printing department, it would only be necessary to refer the reader for instruction in this part of the process to what has been already said on that subject. But this is by no means the case; the calico-printer is much more straitened in his modes of procedure than the dyer, not only in this, but in some of the other styles. If he dyes stuffs of colors which fix themselves without the co-operation of mordants, he has always to combine his mordants in such a manner, that in dyeing simple grounds he shall nevertheless preserve intact the color which he has previously printed, or so that in dyeing with colors which only fix themselves with the assistance of a mordant—and most usually he has several mordants to print beside one another, or in succession to coloring matters already adherent to the stuff—he may be able to saturate individually each mordant with coloring matter without too much straining the parts that are blank or previously colored, which it is his object to reserve, and to give to the stuff on which different colors have been already fixed a new shade which will not injure their appearance.

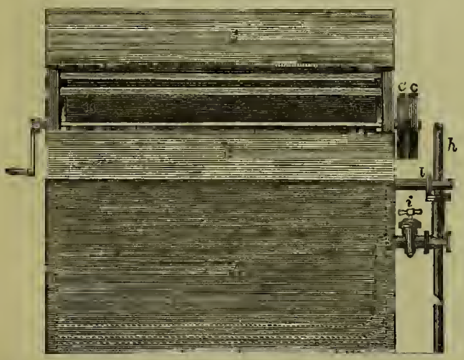
The operation of *maddering*, or dyeing in madder, consists in exposing in suitable circumstances to a bath of madder a stuff charged with one or more mordants which have been imprinted upon it, and fixed by the operation of dunging, and in keeping it under the action of the dye till these mordants have attained the desired shade, or are *saturated.* It was formerly the practice to use, for this operation, copper boilers seated in masonry. These boilers, isolated from one another, were fixed up in a spacious chamber, and surrounded with stages which allowed the workmen to operate all round and at their upper part. Over each of them was adjusted a wince, which a workman put in motion by a handle, whilst two other workmen, placed face to face, at opposite sides of the boiler, passed the pieces by means of poles, the one from the dyestuff over the roller, the other from the roller into the dyestuff; and a third workman was charged with raising the temperature progressively. The pieces not being joined at their extremities in the manner of an endless web, it was necessary to interrupt and change the movement on arriving at one of the ends, to make them dip again into the boiler with a movement opposite to the first course. When the madder bath, gradually heated, came to boil, and the stuff had been made to stay in it for a period varying with the nature and strength of the mordants to be dyed, it was immediately passed to the washing apparatus to be rinsed, and then into the scouring machines, to be perfectly cleaned.

By this mode of operating, it was impossible, whatever might be the attention of the workmen, but that some parts of the stuff should come into contact with the heated sides of the boilers, and that the mordant, modified on these points, should behave differently from that which had not. To combat these injurious effects, different means were resorted to; sometimes the interior of the boilers was lined with strong packing-cloth, sometimes a basket of the same shape as the boilers was inserted within them. Afterwards, the copper boilers, usually ovoidal in form, were replaced by square troughs or vats of the same metal, from six to ten feet in length, which were surmounted with a long reel to admit of turning the pieces mechanically, and without the aid of a workman. Latterly, these copper troughs were generally replaced by wooden ones, heated by steam, which, to the advantage of a greater economy, if not in fuel, at least in manual labor, adds that of not exposing the goods to the accidents which were only too frequent with the former.

For madder-work, however, dye-becks made of iron are now generally substituted for those of wood, as it is found that, when this metal is completely covered with oxide, it exerts no injurious action on the coloring matter.

A steam-generator of sufficient power heats and supplies all the vats or becks of which a dye or print-work consists; this generator is put in communication with these troughs by a large pipe, whence tubes branch off to distribute the steam to each. On the other side, a suitable mechanism gives motion to the winces or reels placed at the upper part of each dye-beck. By means of this arrangement, a good overseer and two or three hands are sufficient to execute, with all the necessary precision, what sixty or even a hundred hands could not formerly manage.

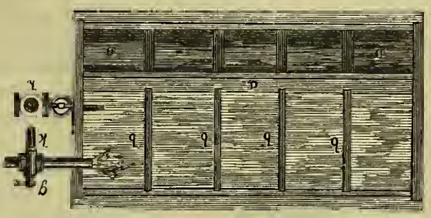
Fig. 392.



The three annexed figures represent, namely, Fig. 392 the elevation, Fig. 393 the plan, and Fig. 394 a vertical cross-section of the dye-beck. The same letters are employed in each to indicate the same parts.

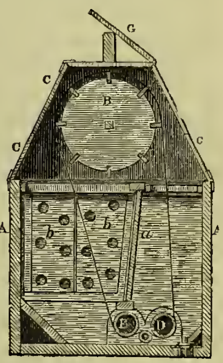
A is a wooden or iron trough, about six feet in length, four feet in width, and four or five in depth, into which the madder and the water required for a dyeing are introduced. This vessel is surmounted with a wince or reel,

Fig. 393.



B, and divided in the direction of its length by a bar, *a*, in that of its width by the four bars, *b*, *b*, *b*, *b*, and thus presents five distinct compartments, into which the goods fall on quitting the reel, B. This reel, containing six or eight long wooden spars on its circumference, is furnished at one end of its axis with pulleys, *c*, *c′*, put in motion by means of a strap driven by any moving power; it is always moved by the hand in dyeing fine fabrics, as muslins, balzarines, *et cetera*. C, C, C, C, are wooden panels or lids with hinges, to be opened and shut at pleasure. The upper two open from below upward, the other two from above downward. D, E, hollow copper rollers, under which the goods pass on quitting the compartments, *b*, *b*, *b*. *f*, a tube pierced with a multitude of holes, through which the steam is introduced at pleasure by the tube, *h*, communicating with a generator. The screw-valve, *i*, affords the means of regulating the introduction of the steam into the tube, *f*. J, a pipe in communication with a reservoir of water, through which, by means of a stopcock, *g k*, which is fitted to it, one can introduce into the trough, A, the quantity of water required for the operation.

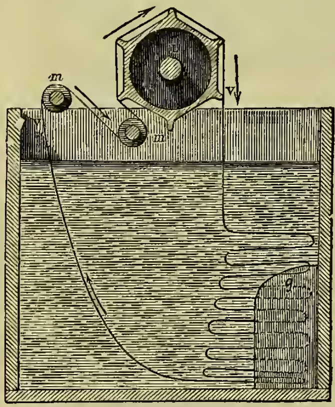
Fig. 394.



The working of this apparatus is very simple: into each of the compartments are put so many as three pieces, if their length permits, but usually two, which makes, in the case represented, ten pieces for each vat. After passing each pair of pieces over the wince, and under the tubes, D, E, they are fastened together by the ends so as to form as many endless webs as there are compartments. The movement is then given to the pulleys, C, C, and the shaft of the reel, being instantly put in motion, draws the goods in such a manner that, passing out from under the cylinders, D, they rise, pass over the reel to fall back into the compartment, *b*, corresponding to each pair, slide over the inclined plane, arrive again under the rollers, D, E, and so on during the whole operation.

It is not difficult to understand the object of placing the partition bars, *b*, *b*, *b*, *b*. If it were not for these, the pieces of the goods, by intermingling, would soon cease to obey the circulating movement which must be given them, and by remaining immovable, would expose, by their resistance, the portions of the stuff in contact with the roller, which would continue its movement, to be torn or more or less damaged, independently of the other injurious consequences which might result to the dyeing. Whatever precautions be taken, however, it will often happen that the goods, when they are too long, and when too many folds accumulate on one point, will still suffer from accidents of this description; and the workmen intrusted with this department must watch attentively to see that they keep up their movement, and hasten to disengage those which might come to a stand, as well to insure the equality of the dyeing as to prevent tearings or weakening of the stuff.

Fig. 395.



At Rouen, where an immoderate length has of late been given to the pieces, the action of the reel is assisted by the use of two traction cylinders, which, by drawing the cloth with more force, prevent it from stopping in its movement. Fig. 395 represents a transverse section of this arrangement. In this figure the parts of the vat which have been previously described are left out.

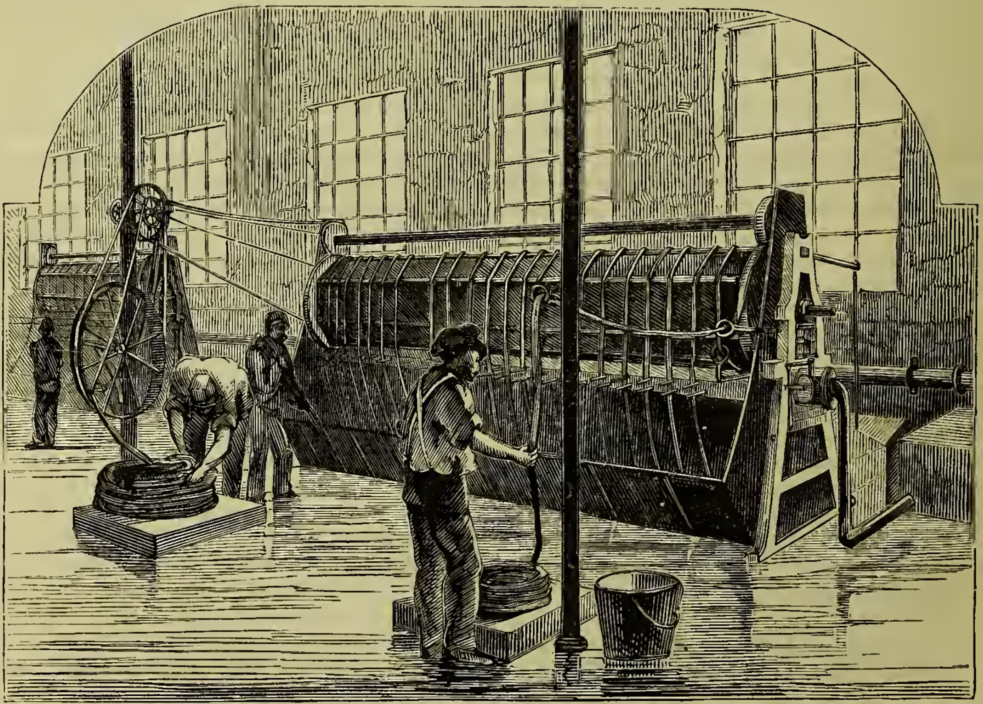
The two cylinders, *m*, *m*, parallel to the wince, L, and fixed at the two ends of the trough, serve to stretch the cloth during the circulating movement which it performs from V to V′, and oppose its remaining immovable and sliding on the sides of the apparatus.

A thermometer is placed in each trough to indicate the temperature of the bath, and to mark its progressive elevation. The subjoined engraving—Fig. 396—exhibits the ordinary dyebeck in operation.

Having thus explained the mechanical operation of the dyeing, it remains to direct attention to the most delicate part of the subject, the chemical and physical action of the different elements which compose it.

One point which it is of paramount importance to keep in mind is, that the madder, whatever be the kind employed, produces bright and fast colors only in the case of its containing chalk, or when the water that is used contains it, or, lastly, when a certain quantity of it is introduced into the dye-bath. This proposition, which was first formulated in a precise manner by J. M. HAUSSMANN, is confirmed by all subsequent writers, among others by PERSOZ, H. SCHLUMBERGER, and DANIEL KŒCHLIN. Hence it is obvious that the results will be different according as the waters employed are pure or hold lime salts in solution, or as the madder contains chalk or not; and, consequently, that it is the interest of the printer to have regard to these circumstances.

Fig. 396.



Madder should be considered, first, with reference to its origin, or rather the soil in which it has been grown; secondly, its age; and, thirdly, the alterations it may have undergone. But as the properties of different madders have been already indicated, a few additional observations on the subject will be here sufficient.

It is beyond doubt, that by employing for a dye, with distilled water, madder which has been gathered in a silicious soil, as that of Alsace. for example, good colors will not be obtained; it is not less certain, that by using the same madder, along with proper proportions of chalk, or with admixture of a madder gathered in a soil essentially calcareous, like those of the Palus soils, which contain so much as ninety per cent. of carbonate of lime. one will obtain, on the contrary, dyes of the brightest description, and having the greatest capability of resistance to the agents which are had recourse to for brightening the colors, and for restoring to their natural whiteness the parts stained by the dye. Chalk is, therefore, one of the indispensable constituents of a good dye. Between the Palus madders, which contain much of it, and those of Alsace, which have not any, there is a great number of intermediate kinds; it would not be necessary to attend to these differences were it possible, without disadvantage to the dyeing, to pass beyond certain limits in the proportion of chalk employed; it would be sufficient to add this substance in excess; but, unfortunately, it is not so, for the chalk, performing the part of a base, may fix a certain quantity of coloring matter, abstract it from the dye-bath, and thus weaken the dyeing power of the madder; it is important, therefore, to proportion the addition of this saturating agent to the nature of the madders, by having regard to the calcareous quality of the water of which use is made.

As regards the age of the madders, it results from observations which are now of very old date, and the fact has been already stated, that madders of a certain age are more favorable for dyeing than madders recently gathered. According to M. H. SCHLUMBERGER, these advantages proceed from an increase of dyeing power determined by the fermentation.

These are PERSOZ'S views on the subject. For the following information the Editor has to thank Mr. JOHN MERCER:—

Madder, according to Mr. DUGALD CAMPBELL, contains a large quantity of the elements of pectic acid, which do not exist in it as such. If mixed with water at 32°, no pectic acid is dissolved out; but he found that at a temperature of 70° to 80°, it afforded large quantities of this acid, and this was the case particularly in those madders containing an excess of lime. This may be seen by mixing ground madder into a thin paste with water at 70° to 80°; in an hour or two the whole becomes a thin gelatinous mass, and, if there be much lime in it, has nearly lost all its dyeing power; for pectic acid, or more so pectate of lime, combines so strongly with the coloring matter of madder, that water will not extract it. Hence, what is called *spent madder* is produced in the dyeing; the pectic acid is quickly generated, and, uniting with the lime, is afterwards dyed, or combines with the tinctorial matter in the dyeing process. This accounts for the greater quantity of coloring matter in the decoction from Alsace madder, often being subjected to the pectic fermentation, in consequence of its containing no lime.

In dyeing with Dutch and similar madders, which have so small a quantity of alizarin fully formed, and so large a proportion of that substance principally in the yellow and orange state, the colors are more of the scarlet hue; these immatured dyes will not resist the action of soap, but they do that of bran well enough. The same may be said of garancin when made from Dutch, Naples, or Alsace madders. The fully-formed alizarin in these cases is but small in quantity, while the immatured substance is abundant. Garancin made from good old Turkey madder, which contains a large quantity of alizarin, dyes all colors as well as the madder from which it was obtained, unless the action of the acid has been too severe; but if so, it imparts the property of dyeing scarlety or rather purplish hues.

Garancin, whether made from fresh or spent madders, dyes good, full, and fast colors. Three pounds of garancin will dye more cloth than four pounds of the same substance ungarancined. Now, garancin contains no lime, although it dyes so well. The most probable explanation is, that the pectic constituents in madder, which, in the process of dyeing, are changed into pectic acid, exercise such a powerful effect on the tinctorial matter as to prevent it dyeing either fast or full hues. Many other substances act similarly when in a gelatinous state, as gum-tragacanth, *et cetera.* To see the effect of starch, for example, on coloring matters, it is sufficient to rub into bleached cotton cloth some thickish starch paste, let it dry, then steep it in some dilute coloring matter—say, cold Japan-wood-liquor—and the spot will come out loaded with coloring matter. A still more interesting experiment, to show the powerful attraction of one form of starch on coloring matter, is the following:—Add two equivalents of water to oil of vitriol, so as to form terhydrated sulphuric acid; let drops of this fall on bleached cotton cloth; at these spots the fibre will become transparent starch; steep and rinse in water till all the acid has been removed, then immerse in cold dilute Japan or logwood bath, *et cetera*, and the spots will acquire coloring matter sufficient for a full red or black, with aluminous or iron mordant, as the case may be.

Another corroboration of the injurious effect of pectic acid is the following:—It is well known that a large quantity of coloring matter is held insoluble by this acid and lime. When spent madder is steeped in cold dilute hydrochloric acid for some time, and then well washed with cold water, the product dyes weak fugitive colors, because the pectic acid is not dissolved and removed by so dilute an acid; but if it had been heated, then both the lime and pectic acid would have been removed, and it would afford rich colors.—*Mercer*

When water is practically pure, like that which supplies some establishments, or like the water of condensation of steam-boilers, which is at present turned to account in many dyeworks, the remarks to be made on this subject have reference only to the proportion of water to be used, to the manner in which the bath should be heated, and to the temperature it ought to reach; when, on the contrary, the waters are charged with saline matters, like those which spring from tertiary soils, the printer must study them with care to apply to them the proper correctives. If charged with bicarbonate of lime only, which is very rare, their effect is to fix, in pure loss, a certain quantity of coloring matter, to prevent which different means are employed.

Occasionally the water is heated to disengage the portion of carbonic acid which constitutes the bicarbonate, and precipitates the neutral carbonate; but this process is expensive.

Often the water is saturated with a suitable proportion of sulphuric acid, or of oxalic acid, if the price of this latter is not too high. In this case a gallon of water is taken, and, by means of a standard liquor, one ascertains the quantity of the one or the other of these acids necessary to saturate the lime of the carbonate which the liquid contains; then, having established this point, the proportion of acid required by the volume of water which should serve as a dye-bath, is known at once by calculation. If the sulphuric and oxalic acids are employed here in preference to all others, it is on account of their great affinity for lime, an affinity so great, indeed, that the coloring matter which acts the part of an acid can scarcely displace them.

At times the water is saturated with a quantity of lime equal to that which exists in the bicarbonate; but this method, which should be used with great circumspection, since the least excess of lime would be sufficient to attack and dissolve the mordants of alumina, is only practicable in two cases, on account of the large amount of chalk which it generates—either when use is made of madder totally free from chalk, or when one has at disposal a large reservoir or basin in which to effect the double decomposition, and from which the water is decanted off only after remaining so long at rest that the carbonate of lime, which is formed at the expense of the elements of the bicarbonate and lime, is in great part deposited.

Sometimes caustic potassa and soda are employed, and this is the method which the greater number of printers have recourse to; sometimes, but more rarely, on account of the expense which this process incurs, barley bran is used.

When the waters contain, along with bicarbonate of lime, a certain quantity of chloride of calcium, and this is most generally the case, it is necessary to have recourse to other contrivances. When one has determined, by exact experiments, the quantity of the last-named ingredients contained in the liquid intended to be used, to the latter may be added the proportion of caustic soda or caustic potassa—experience has taught to give the preference to the latter—necessary to saturate the free carbonic acid, of which the bicarbonate is constituted. Then the alkaline carbonate which is formed, reacting on the chloride, determines a double decomposition, which has for effect to carry the carbonic acid on to the lime of the chloride, whilst the sodium or potassium remains in combination with the chlorine.

Instead of potassa and soda, one may employ with the same view a certain quantity of spent soap. The latter, by its base, saturates the acids, and, by the fatty acids which it contains, renders insoluble and precipitates the lime which the water holds in solution. This method is more sure, but also much more expensive. As the efficacy of the soap in this operation has been contested, the value of the objections urged to the intervention of this body in the operation of maddering will be explained in a future page.

To combat the effects of the lime which is found in the water, and which has the effect not only of absorbing a certain quantity of color in pure loss, but further of injuring the shades and staining the blank parts, astringent substances are likewise used, such as nut-gall, quercitron, and especially sumach. These bodies having a greater tendency to form combinations with the lime, dispute it with the coloring matter of the madder, and thus render the dyeing better and more economical, at least for certain shades.

Lastly, for certain kinds, recourse is had, with more or less success, to other substances; thus gelatin is used in the dyeing of black from logwood grounds with reserve mordant, and at one time euphorbia was employed.

When the waters contain sulphate of lime, the action of which is less hurtful than that of the chloride of the same base, they are corrected by adding a suitable proportion of carbonate of potassa or caustic potassa, according as they hold in solution sulphate only, or a mixture of that salt and bicarbonate of lime.

The magnesian salts, behaving to a certain extent like the lime salts, the same means are employed to clear the water of them.

The iron which is met with in waters has for its result, not only to occasion losses of coloring matter, but further, and which is more troublesome, to affect the shades of the madder so much, that it is impossible to obtain rose-colors with it. Now, even when the printer has assured himself by all the means at his disposal that the water which supplies his establishment is fitted for the operations of dyeing, he is liable to see it become accidentally ferruginous from two causes. If this water has torrents running into it, these may carry into it clays strongly ferruginous; but, in this case, by leaving the liquid to settle, or filtering it, one may guard against the disadvantages which would be occasioned by the presence of these substances, which always fix, in pure loss, the coloring matter of the dye-bath. On the other hand, if all the water, or a part only, runs or rests on marshy soils, or such as are impregnated with organic deposits, it may temporarily get charged with iron; for, the decomposition of the organic matters in presence of water having the effect of transforming into sulphide the iron which exists in a submerged soil, when this sulphide is formed and the level of the water sinks, an opposite effect is produced—the sulphide oxidizes, passes into the state of sulphate, or subsidiarily into that of bicarbonate, and as soon as a sudden flood takes place, the waters which again cover these lands, getting charged with those salts, transport them in solution to a distance. To correct waters of this nature, it is best to make use of a certain quantity of phosphate of potassa, which precipitates the iron in the state of a phosphate; this salt absorbs, indeed, a good part of the coloring matter, but at least does not injure the purity of the shades. There are printers who employ cream of tartar, adding about an ounce to the dye-beck. The office of this saline compound is to mask the oxides.

In many printing establishments, the waters are submitted to a filtration, which is effected by different methods—in some cases by constructing large basins, in which the water is previously subjected to a decomposition, which separates the salts from it.

Assuming the printer to have decided on the nature of the madder, the proportion of chalk to be added to it, the quality of the water, and the best corrective for it if it be not pure, the next points to be considered are the most favorable conditions for good madder-dyeing, and then the influence which may be exercised on this operation by the different agents that may intervene.

Is it proper, after mixing the madder with water, to leave it to macerate during a certain time before proceeding with the dyeing? From an Avignon madder, macerated at 32°, and then filtered, a liquor strongly colored was obtained, which, when heated in the ordinary manner, dyed the mordanted samples which were dipped into it pretty well; on the contrary, this same root, macerated in a water heated to 86°, yielded, on being filtered, only a liquor which scarcely possessed the property of dyeing. On the other hand, the madders of Alsace, in the same conditions of temperature, yielded infusions almost equally rich in coloring principle. The following is a table of the results which M. **Henri Schlumberger** established with reference to this question, by macerating separately, during fifteen minutes, forty-six grammes—seven hundred and thirteen grains—of Avignon madder, and the same quantity of Alsace madder in 1·5 litres, or one-third of a gallon of water, at different temperatures:—

Temperature at which the maceration took place.	Intensity of the shade obtained expressed in weights of madder.	
	Avignon madder.	Alsace madder.
32° temperature,	6 grammes,	9 grammes.
54° “	2 “	7 “
86° “	1 “	5 “
122° “	2 “	6 “

These experiments prove that the maceration of the madder in warm water has nothing but a prejudicial effect.

It has likewise been established that the macerations of the madder are favorable only in so far as this root undergoes a fermentation which has for its result to effect the destruction of the foreign ingredients which accompany it, and by setting at liberty the coloring matter, to render it more apt for the dyeing; but as no one has yet succeeded in stating the precise conditions in which this molecular change would be brought about in a regular manner, it has not hitherto been possible to make a practical application of this fact demonstrated in the laboratories of chemists.

From these experiments there follows, in a practical point of view, this consequence, that in proceeding to the dyeing, the madder and chalk should be mixed with water, incorporating the powder with the liquid as thoroughly as possible. For this purpose it is best to begin by wetting the madder with a small quantity of water; then, when it is well divided, and the knots or clots have completely disappeared, the rest of the liquid is added.

As regards the quantity of madder to employ for dyeing a limited number of pieces, it is difficult to determine this in an absolute manner: it varies, first, according to the quality of the madders; second, according to that of the waters; third, according to the kind of patterns, which, as they are more or less charged with mordant, consume more or less coloring matter; fourth, according to the manner in which the mordanted goods have been dunged and scoured; for when this operation has been imperfect, the portions of mordant which were not properly fixed on the stuff get detached from it, and yet absorb coloring matter; fifth, according to the modes of brightening or bleaching which have succeeded to the dyeing, and which more or less degrade the coloring matters fixed on the stuff by the mordants; sixth, according to the degree of temperature at which the dyeing is performed, because the kinds which require a low temperature demand a larger proportion of madder than those whose shade stands a higher temperature; seventh, according to the nature of the goods, for a mordanted jaconet, muslin, or light calico, requires less madder than strong and close calicoes, which fix a proportionally larger quantity of mordant.

The quantity of water which should be employed in a maddering is a point of not less importance, since the proportions of this liquid more or less modify the dyeing power of the same madder; but it is for the printer to regulate these quantities according to the quality of his water, and the conditions in which it operates, for unfortunately the data hitherto furnished in reference to this matter present too little agreement among themselves to be depended on.

In the next place, is it a matter of indifference to immerse the pieces dry or moist, cold or warm, into the dye-bath? With a little attention one must be convinced that it is more advantageous to introduce them into it dry than damp; if the color penetrates less equally at the outset, it fixes itself more rapidly. As regards the second part of the question, which many persons may consider an idle one, all the other circumstances being equal, there is a decided saving of madder by introducing the goods warm into a dye-bath, and the saving is still greater when one makes them pass directly from over a jet of dry steam into the bath. This difference is explained by the consideration, that the air expelled by the heat from the pores of the stuff, allows the colored liquid a freer access to them, by the partial vacuum which is produced at the moment of immersion.

With regard to the exact temperature at which the goods and the madder should be introduced into the water, an able anonymous German writer has shown that the most favorable temperature for dyeing is 120°; that at this temperature one obtains a result of + 31 of dyeing effect, whereas at 190° one obtains with the same madder only — 31, a difference of 62 per cent. Lower, and especially higher temperatures always give, according to the same authority, less favorable results. These experiments have been varied and confirmed, in all their essential points, by M. H. **Schlumberger**, who dyed for two hours, beginning with temperatures comprised between 32° and 212°, and always bringing the baths to ebullition, equal samples with the same weights of madder, and the same volumes of water. The results were as follow:—

Temperature of the water at the beginning of the dyeing.		Expression of the shade obtained in positive or negative quantities of madder. The normal shade = 0.
32°	temperature,	— 26 per cent.
68°	“	— 17 “
104°	“	0 “
140°	“	+ 17 “
176°	“	— 17 “
212°	“	— 50 “

According to these results, there would be a great economy in entering upon the dyeing at 120° or 140°, since it is the most favorable degree of temperature; but one cannot apply these data to practical operations, first, because there are shades, like madder rose, which dye only at much lower temperatures; next, because a too rapid dyeing is rarely uniform in its results; and, lastly, because colors at temperatures above 70°, 80°, and 100°, do not so well resist the operations of brightening, since, in this case, the coloring matter, which precipitates with too much energy on the stuff, being immediately absorbed by the surface of the mordant, with which it forms as it were a crust, does not penetrate the interior of the latter, and consequently the greater part of it disappears in the operations which follow the dyeing.

A point to which too much attention cannot be given is, that it is always of importance to raise progressively the temperature of a madder bath, or at least to maintain it stationary, for experience has shown that this temperature cannot be let down, to be raised again, without suffering great losses of coloring matter. Thus M. HENRI SCHLUMBERGER showed that a madder bath, after being brought to 130°, cooled again to 90°, heated anew to 160°, again cooled to 100°, and finally brought to ebullition, had lost 40 per cent. of its dyeing power.

Lastly, to abstract the whole of the dyeing substance from a madder, may the dyeing operation be prolonged for a longer or shorter time, or does it answer best to limit the duration of the maddering, by raising the bath during a certain lapse of time to an elevated temperature? The anonymous authority to whom reference has been made, affirms that the duration of a maddering should be limited; that it should be accomplished in the space of two hours, taking the precaution to raise the bath progressively to ebullition; that beyond these limits there is loss of coloring matter, and, likewise, if the dyeing is prolonged, of labor, fuel, and time. M. HENRI SCHLUMBERGER, who is not of this opinion, and who has the results of experience in his favor, has shown that the duration of a maddering may be prolonged during four or five hours, provided the temperature of the bath is kept up at the same degree, or progressively raised. The subjoined table exhibits a summary of the experiments which he made on this subject:—

Duration of the dyeing.	Duration of the boiling.	Results of the dyeing expressed in positive and negative quantities of madder.
½ hour,	5 minutes,	— 25 per cent.
1 “	10 “	— 15 “
2 “	15 “	0 “
3 “	30 “	0 “
4 hours,	30 minutes,	+ 8 per cent.
5 “	40 “	+ 8 “
6 “	40 “	+ 8 “
7 “	40 “	+ 17 “
8 “	60 “	+ 17 “

These experiments establish in a convincing manner, that by prolonging a dyeing, far from experiencing a loss, one derives on the contrary greater advantage from the coloring matter; at the same time, it would be an error to conclude that it is proper in all cases to prolong the maddering; it must first be considered whether the economy in madder is compensated by the expenses of labour, fuel, and time. Lastly, another fact should be taken into consideration, namely, it seems a general rule that the colors due to a prolonged dyeing do not generally resist the brightenings so well. It has been shown that a too rapid dyeing, or one performed in too short a time, is defective, inasmuch as that the coloring matter, depositing itself at the surface of the mordant, does not reach the centre; a too prolonged dyeing is not less so, seeing that in this case the foreign substances in the coloring matter, which always more or less attack the mordants, produce on them the effect of actual discharges.

To ascertain if it be necessary to bring the dye-bath to ebullition, in order to abstract from it the maximum of coloring matter, M. HENRI SCHLUMBERGER performed several dyeings at different temperatures, both with Avignon and Alsace madder, prolonging the duration of a certain number of these dyeings for three hours, and others for eight; the following table contains the results of his operations:—

Temperatures at which the dyeings were Commenced.	Terminated.	Results of dyeings of three hours' duration.		Results of dyeings of eight hours' duration.	
		Avignon madder.	Alsace madder.	Avignon madder.	Alsace madder.
		Per cent.	Per cent.	Per cent.	Per cent.
at 32° ..	at 32°	— 95	— 95	— 95	— 95
50° ..	50°	— 96	— 92	— 89	— 89
68° ..	68°	— 89	— 79	— 70	— 79
86° ..	86°	— 79	— 70	— 30	— 46
104° ..	104°	— 55	— 58	0	— 22
104° ..	122°	— 38	— 46	+ 17	— 14
104° ..	140°	— 22	— 38	+ 17	— 6
104° ..	158°	— 14	— 24	+ 17	0
104° ..	176°	— 6	— 6	+ 17	+ 8
104° ..	203°	0	0	+ 17	+ 8
104°	Ebullition.	+ 8	+ 6	+ 17	+ 8

From this table the following conclusions may be drawn:—

1st. That, for dyeings of short duration, the temperature of the bath must be elevated, if one wishes to extract from the madder the maximum of coloring matter, since, for dyeings with Avignon and Alsace madder, of three hours' duration, the normal shade is obtained only at 203°; that below this there is loss, and that an augmentation is obtained only by ebullition.

2d. That, on the contrary, for prolonged dyeings, it is not necessary to raise the temperature so high, since a bath heated from 104° to 122° during the space of eight hours, gives the same results as if it were at ebullition. This point is not without importance, for the necessity of always raising a madder bath to the boiling point, in order to obtain from it the maximum of coloring matter, would be attended with serious disadvantages.

3d. That there is loss of a large quantity of coloring matter in dyeings under 104°; but that this loss goes on diminishing in proportion as the temperature approaches that point, or nearly the point at which the maddering is most effectually done. It is to be remarked, nevertheless, that certain shades, such as pale rose-color, can only be obtained at very low temperatures; in that case care is taken to utilize for other styles the strong proportion of coloring matter which the residue of the maddering bath still contains.

4th. That from 104° and upward, the Alsace madder, all other circumstances being equal, requires, in order to yield its coloring matter, a higher temperature than Avignon madder; that the contrary takes place at temperatures under 104°.

With regard to the influence of the air, it cannot be doubted that it exercises an action on the madder, for, in contact with a fresh bath of this root, it reddens it and precipitates the coloring matter from it; but is this action favorable or otherwise to the dyeing, both in regard to the development of dyeing power and the durability of the shade? In the knowledge of the fact that Alsace madder, though incapable by itself of giving good and durable shades, acquires, along with this property, a greater richness when it has been long in contact with the air, one is led to decide in the affirmative; nevertheless, a difference of opinion still exists on this point.

The next subject to be considered is the influence exercised on the dyeing by the foreign bodies which may be introduced into a madder bath. M. Henri Schlumberger was the first who turned his attention to this question. Having found that the absence of chalk is the only character which distinguishes the Alsace madder from that of Avignon, and knowing, moreover, from the experiments of Haussmann, that this carbonate is indispensable to a good dyeing, he wished to see if there were other bodies capable of giving to the Alsace madder the property of dyeing like the Avignon madder; that is to say, so as to stand the clearing processes. The experiments to which he addressed himself prove, that if there are some substances which, to a certain extent, are capable of replacing the chalk, as phosphate of lime for example, there are others, such as the oxide and carbonate of copper, which exercise an action so unfavorable as to frustrate the dyeing.

Subsequently to the publication of Haussmann's results, the anonymous author already cited addressed, in 1835, to the Industrial Society of Mulhouse, a memoir entitled, *Researches and Results on the Means of Extracting, by Dyeing, the Greatest Quantity of Coloring Matter from Madder*, in which he examines successively the action of a multitude of substances on a madder bath. Although the results obtained by this observer have not all been confirmed, there are a certain number of them which present sufficient interest to make it desirable to reproduce them here. To establish these results, he conceived the happy idea of forming, with determinate proportions of pure madder, two very extended scales, with which he might compare the products of his different dyeings. To form these scales, he took four equal pieces of cloth, two of which he padded with mordants of alumina, the one very strong, the other very weak; the other two with mordants of iron, corresponding in strength and weakness to the first two. Setting out with a madder bath extremely weak, he successively dyed equal portions of cloth padded with weak mordants, with greater and greater proportions of madder, till he had found the weight of its powder necessary for the saturation of the mordant. After thus obtaining gradations of tints corresponding to proportional weights of madder, he repeated the same operations on strong mordants, but beginning with a proportion of madder just above that which he would have had to employ to arrive at the saturation of the weaker mordants, and he established a new scale of tints, equally corresponding to known weights of madder, and which, joined to the first, gave him an uninterrupted scale of shades, each tone of which corresponded to known proportions of madder. Then, by operating, for all his further experiments, on similar surfaces of cloth mordanted in the same manner, and on a quantity of madder equal to the mean weight of the two extreme tones of the scale, he would evidently find that the shade of a dyeing made with a constant weight of madder of the same quality would be equal either to that of the normal scale, which is represented by 0, or zero, or to that which would result from the use of a stronger or weaker proportion of madder, represented in that case by the sign +, or the sign —, followed by the figure which indicates the quantity of the dyeing substance.

Such is a condensed statement of the ingenious process which he followed to procure the means of determining the influence exerted by a great number of foreign bodies on a dye-bath. The different tables in which he embodied the results of his experiments will now be given, following each with the reflections which it suggests:—

Effects produced by ammonia and alkaline compounds on dye-baths.

				Per cent.
1-60th	of the weight of the madder		in carbonate of potassa gives	— 5
1-60th	Do.	do.	in carbonate of soda,	— 8
1-60th	Do.	do.	quick lime,	—30
1-60th	Do.	do.	carbonate of lime,	—46
1-20th	Do.	do.	ammonia,	— 5
1-60th	Do.	do.	ammonia,	—28

This table shows that alkalies and alkaline salts, when added to a madder bath, diminish its tinctorial power.

Effects produced by the earthy and metallic oxides on dye-baths

				Per cent.
1-120th	of the weight	of madder	in magnesia gives	— 16
1-60th	Do.	do.	in carbonate of magnesia,	— 13
1-60th	Do.	do.	oxide of lead,	— 11
1-60th	Do.	do.	oxide of zinc,	— 26

If the author had studied in the same manner, says Persoz, all the metallic oxides, he would have found, with M. Henri Schlumberger, that several of these bodies, especially the oxide, hydrate, and carbonate of copper, added, even in small proportions, to a dye-bath completely destroy its power.

Effects produced by the acids on dye-baths.

				Per cent.
1-120th	of the weight of the madder		in sulphuric acid at 162° Twaddell produces	— 22
1-120th	Do.	do.	in hydrochloric acid at 36°,	— 20
1-120th	Do.	do.	nitric acid at 66°,	— 9
1-120th	Do.	do.	tartaric acid,	— 23
1-120th	Do.	do.	oxalic acid,	— 17
1-120th	Do.	do.	citric acid,	— 22
1-60th	Do.	do.	vinegar,	— 6
1-120th	Do.	do.	boric acid,	— 7
1-120th	Do.	do.	benzoic acid,	+ 21
1-60th	Do.	do.	arsenious acid,	+ 6
1-120th	Do.	do.	phosphoric acid,	+ 8

The presence of almost all the acids is, therefore, according to this table, unfavorable to a madder dyeing; the benzoic, arsenious, and phosphoric acids make the only exceptions, since, with these agents, the madder furnishes richer or more intense hues. This result, generally admitted as regards the arsenious and phosphoric acids, is contested in the case of the benzoic acid. It will not appear surprising that the acids should be hurtful to a dyeing, if one considers the part performed by the coloring matters, which, while themselves acting as acids, but with feebler power, are displaced by them, and become in their presence insoluble, or scarcely soluble, and consequently unfitted to combine with the bases; but even this very part which they perform enables one to conceive how the acids which are regarded as exerting a pernicious action on the dyeing—sulphuric and oxalic acids, for example—may nevertheless, in certain circumstances, become useful auxiliaries. If a dyeing, for instance, has been performed with a Palus madder and distilled water, or with Alsace madder and chalk, and the bath has been so much exhausted as to yield nothing more to the mordants, a suitable addition of sulphuric or oxalic acid will, by giving it a certain degree of energy, have the effect of rendering this bath still capable of dyeing. In fact, the phenomenon which takes place during the maddering is as follows: a portion of the tinctorial matter becomes fixed on the lime, and when once engaged in such a combination, becomes unfit to dye; but if the acids above mentioned be interposed, this combination is destroyed, and the coloring matter, set at liberty, exerts its action on the mordants. If, however, the acid employed should be in such quantity as to predominate, the coloring matter would produce no further effect, either because it would become insoluble, or because, naturally weaker, it would not be able to dispute with the acid the power of combining with the mordants. This experiment, which Persoz repeated several times, both with oxalic and sulphuric acid, always succeeded, by taking care to add to the bath only a small part at a time of the quantity of acid judged necessary, and to withdraw at each addition the sample of mordanted cloth which was in that bath.

Effects produced by saline compounds on dye-baths.

				Per cent.
1-60th	of the weight of the madder		in sulphate of potassa yields	+ 25
1-60th	Do.	do.	in sulphate of soda,	— 21
1-60th	Do.	do.	chloride of sodium,	— 9
1-60th	Do.	do.	nitrate of soda,	— 10
1-60th	Do.	do.	tartrate of potassa,	— 31
1-60th	Do.	do.	oxalate of potassa,	— 29
1-60th	of the weight of the madder		in acetate of potassa, yields	— 7
1-60th	Do.	do.	in acetate of soda,	— 10
1-60th	Do.	do.	chromate of potassa,	+ 26
1-60th	Do.	do.	bichromate of potassa,	+ 28
1-60th	Do.	do.	arseniate of potassa,	+ ·5
1-60th	Do.	do.	chloride of calcium,	— 28
1-60th	Do.	do.	sulphate of lime,	+ 7
1-60th	Do.	do.	phosphate of lime,	+ 16
1-30th	Do.	do.	moist phosphate of lime	+ 42
1-60th	Do.	do.	acetate of lead,	— 34
1-60th	Do.	do.	alum,	— 40
1-60th	Do.	do.	soap,	+ 18

It is very remarkable that two compounds so like each other as the sulphates of potassa and soda exercise an action so dissimilar, that there should be a difference of forty-six per cent. in favor of the former. If it were only required to explain why the sulphate of soda is hurtful, whilst the sulphate of potassa is not so, the cause of it might be found in the power which the former possesses of forming combinations with the water, which it disputes with the coloring matter, and consequently the latter, without a suitable vehicle, becomes unfit to accomplish its action; but there is something more required to account for the positive part performed by the sulphate of potassa, which is still a mystery. Whatever it be, it is not the less true that a long experience has convinced dyers of the necessity of employing potassa, and not soda, to correct the calcareous waters intended to be used in maddering, which proves, further, that the salts of potassium—chloride and sulphate—which are formed and remain in solution in these waters, are more favorable than the corresponding salts of soda.

Of all the saline compounds employed, the hydrated phosphate of lime is that which produces the most effect; doubtless it is to the portion of phosphoric acid in its composition that it owes in part this property.

The soap exercises also a favorable influence, as the following experiment attests:—When a madder bath is exhausted by the dyeing of mordanted stuffs, one can always, by adding to it a certain quantity of this compound, dye, though in weaker tones, fresh goods, especially when they are mordanted for violets. In such circumstances the dyeing is effected without the blank parts being stained.

Several dyers make use of soap, with the view of utilizing their residues of madder, and it has been affirmed that soap added to an exhausted bath effects an economy of one-fourth to one-third of the coloring matter. M. Henri Schlumberger, having undertaken some experiments in connection with this subject, alleged that an addition of soap to an exhausted dye-bath neither renders the coloring matter soluble nor fit for dyeing; that it is, on the contrary, always hurtful, and is consequently far from increasing the extraction of the tinctorial matter. To explain an opinion so different from the general belief, it must be assumed either that he operated on a soap of peculiar quality, or that he employed it in peculiar proportions, for soap must necessarily cause the compound of coloring matter and lime which exists in the residue of a maddering to undergo a double decomposition, the result of which is the production of an insoluble calcareous soap, and of a combination of the coloring principle with the alkaline base of the soap, which, momentarily soluble, yields its coloring matter to the mordant at the instant of its being destroyed. This so natural explanation is the only one which can account for the part performed by the soap in the bleaching of the unmordanted parts of a stuff, which are more or less stained by a portion of the tinctorial principle combined with the lime on passing into a dye-bath.

Effects produced by vegetal and animal substances on dye-baths.

			Per cent.
1-10th	of the weight of the madder	in wheat bran yields..	— 17
1-10th	Do.	in wheat bran mixed with boiling water,	— 8
1-30th	Do.	wheat flour,	— 8
1-30th	Do.	oatmeal,	— ¼
1-30th	Do.	starch,	— 27
1-30th	Do.	salep,	— 13
1-30th	Do.	gum arabic,	— 10
1-30th	Do.	gum tragacanth,	— 18
1-30th	Do.	sugar,	+ 28
1-60th	Do.	salicin,	— 14
1-30th	Do.	linseed meal,	— 9
1-30th	Do.	starch-gum—roasted starch,	+ 13
1-30th	Do.	barleymeal with bran,	— 13
1-30th	Do.	peasemeal with bran,	— 17
1-30th	Do.	sumach,	— 5
1-30th	Do.	pulverized gall-nut,	+ 24
1-15th	Do.	do.	+ 34
1-30th	Do.	ratanhia,	— 16
1-30th	Do.	catechu,	+ 11
1-30th	Do.	oak-bark,	+ 25
1-30th	Do.	willow-bark,	+ 13
1 30th	Do.	pine-bark,	+ 17
1-30th	Do.	bark of pomegranate,	+ 53
1-30th	Do.	fir-bark,	+ 13
1-30th	Do.	oak saw-dust,	— 14
1-30th	Do.	alder saw-dust,	— 21
1-30th	Do.	quercitron,	+ 27
1-30th	Do.	quassia,	+ 42
1-30th	Do.	marsh clover,	+ 32
1-30th	Do.	aloes,	0
1-30th	Do.	ox-blood,	+ 39
1-30th	Do.	albumen,	+ 4
1-30th	Do.	milk,	+ 15
1-30th	Do.	ox-gall,	— ¼
1-30th	Do.	cow-dung,	— ½
1-30th	Do.	strong glue—gelatin,	+ 4
1-30th	Do.	strong glue dissolved in warm water,	— ¾

Several of the results recorded in this table are only the confirmation of facts long known by experience. It shows that the advantage derived from ox-blood, which is always used in Turkey-red dyeing, is + 29 per cent. The astringent substances formerly in constant use figure in it also with positive signs; and it may be remarked, that the action of these substances must not be confounded with that of the acids and of the saline compounds which have been specified, seeing that they intervene directly in the dyeing by being added to the coloring matter of the madder. Thus a mordanted cloth, dyed in a madder-bath to which quercitron or sumach powder has been added, takes a red color slightly orange, which alone proves that a certain quantity of the yellow coloring matter is fixed to the mordant of alumina; but let this cloth be covered with a mordant of iron, and one can no longer doubt that an astringent substance adheres to it, for the red part, instead of becoming puce, will become black, in consequence of the reaction which will be established between the tannin and the oxide of iron.

One may likewise see in this table the sensibly negative effect of the cow-dung, which some printers are in the habit of adding to their maddering; and lastly, that it is not indifferent to employ, either cold or in a dissolved state, the gelatin of which such frequent use is made.

Effects produced by the sulphides on madder-baths.

				Per cent.
1-30th	of the weight of	madder	in tersulphide of arsenic—orpiment—yields	+ 36
1-30th	Do.	do.	in bisulphide of arsenic—realgar—gives	+ 3
1-60th	Do.	do.	in sulphide of potassium,..	— 20
1-30th	Do.	do.	in sulphide of calcium,...	— ¼

This table shows the favorable action of the tersulphide of arsenic—orpiment—in dyeing. There is nothing surprising in this result, especially when the maddering is performed at ebullition, because at this temperature the tersulphide, decomposed by water, is transformed into sulphide of hydrogen, which is disengaged, and into arsenious acid, which remains in solution, as shown in the following equation:—

$$\underbrace{\mathrm{As\,S_3}}_{\text{Tersulphide of arsenic.}} + \underbrace{3\,\mathrm{HO}}_{\text{Water.}} = \underbrace{\mathrm{As\,O_3}}_{\text{Arsenious acid.}} + \underbrace{3\,\mathrm{HS}}_{\text{Sulphide of hydrogen.}}$$

Now, as this last has a sufficiently decided positive power in the maddering, it is natural that the compound which gives rise to it in the very circumstances of the operation should be possessed of the same property.

Having passed in review the bodies which have some influence on madder dyeing, it now remains to explain, if possible, the action which they exert.

That which has the most remarkable effect is unquestionably the chalk, which gives to the Alsace madder a power that it does not possess by itself. The specific characters of this madder are such that some dyers, still refusing to admit the identity of its coloring matter with that of the Avignon madder, maintain that the dyes which it forms do not stand the clearing processes, and that it cannot be used for certain styles.

When Messrs. DANIEL KŒCHLIN, H. SCHLUMBERGER, and PERSOZ, endeavored to account for the important part performed by the lime in the operation of maddering, a twofold question presented itself to them:—Has this body no other effect than to neutralize an acid, the existence of which has been more than once pointed out in madder, or does it become an integral part of the colored combination which is effected on the stuff itself?

The first of these modes of viewing the action of the chalk is that which generally prevailed formerly, without any other reason than the simple fact of the use which is made of it; but if the chalk were in this case only a saturating substance, every other similar compound ought to conduct to the same result. Now, it is demonstrated that a great number of bodies endowed with at least an equal power of saturation, not only communicate no permanence to the madder, but even become an obstacle to its fixation on the mordants, and occasion great losses of coloring matter. In fact, the phosphate of lime, the carbonates of potassa and soda, replace, to a certain extent, the chalk; but it is natural to inquire, on the one hand, whether the phosphate does not yield to the bath a certain quantity of its base; and, on the other hand, whether the carbonates, by the double decomposition which they produce in all the soluble and insoluble salts, have not equally the effect of indirectly bringing the chalk in contact with the madder?

It was from these considerations, and guided, moreover, by others of a different nature, that the above-named chemists directed their labors, and examined whether the chalk does not contract an intimate combination with the alumina and the coloring matter. For this purpose, after having purified some yards of calico by reiterated treatments with acids, they padded them, some with iron mordant, others with alumina mordant, and dyed them in baths of distilled water and Alsace madder in suitable proportions, with and without the addition of chalk. Having then burned and incinerated the samples so dyed, they submitted their ashes to analysis, and found that those of the stuffs dyed with addition of chalk contained in ten square inches of burned cloth 2·5 grains of lime, those of the cloths dyed without chalk only eight-tenths of a grain, a quantity sensibly equal to that which is found in the ashes of a white purified stuff.

As the lime found in the goods dyed without chalk might quite as well proceed from a mechanical adherence of this substance to the stuff during the maddering, as from the fact of a combination during the dyeing, they submitted other samples prepared in the same manner to the operations of clearing, that is to say, to treatments with soap, acid, and again with soap; they then burned them, and their ashes gave quantities of lime and alumina, which were found in atomic or proportional relations; that is to say, there were sensibly two equivalents of oxide of alumina and three equivalents of oxide of lime.

Then, after several treatments with acetic acid to take away the chalk, they burned a great number of samples dyed rose-color, ordinary red, and Turkey-red, and the analysis of the ashes proceeding from the incineration of these goods constantly proved the existence of alumina and lime in a simple and invariable relation; so that one might, without too much temerity, lay down this proposition, that the operations of clearing which succeed to those of the maddering, wherewith they are intimately connected, have no other effect than to form a definite quaternary and colored combination, or lake, composed of *lime*, of *alumina* or *iron*, of *coloring matter*, and *fatty bodies*.

It will be objected, perhaps, to these results, that alizarin yields fast colors directly, without the concurrence of chalk, that hence it is necessary to admit either that this tinctorial matter is not the same as the madder, or that, if it be so, the chalk does not play the part which has been attributed to it; but the trials which have been made with alizarin on mordanted goods do not show, in an absolute manner, that it forms on the stuff colored and fast lakes without the intervention of the chalk. The mordanted goods are always, in fact, passed into a dung-bath; now, would not this bath, which naturally contains phosphates and carbonates, and to which, moreover, a certain quantity of chalk is always added, yield to the stuff, notwithstanding the most perfect washings, a sufficient proportion of this substance to form the definite and colored combination which constitutes the lake?

In connection with his previous remarks on pectic acid, Mr. MERCER says:—To increase the dyeing properties of madder, the English dyers use only the astringent vegetals; and these combining with the pectic acid and lime, render these less destructive to the dyeing power of the madder. In Turkey-reds, blood is well known to be almost indispensable; now, the spent madder of Turkey-red dyeing contains little or no coloring matter. Does the blood being always putrid prevent the pectic fermentation, or generation of pectic acid; or, at the time of coagulation, does it cease to hold both the lime and pectic acid? The probability is, that there is no pectic acid formed. As a partial corrective of the injurious effects of this acid in madder dyeing, sumach, valonia, bark, *et cetera*, have long been, and are still greatly used. These astringent vegetals also improve the solubility of most coloring matters in water. They likewise add firmness to the compound or lake of the mordant and feeble coloring matters, such as peachwood, *et cetera*. From the foregoing remarks, it appears to Mr. MERCER that the beneficial use of chalk is mostly due to its power of taking or keeping down the pectic acid.

On the whole, as regards the mode of action of the substances which develop, mask, or destroy the dyeing power of madder, the knowledge acquired is still too limited to admit of giving a full explanation of it. If the oxide of copper and its derivatives destroy the power of this dye-stuff, the reason of it is found in the very combination which is then produced, since the coloring matter and the metal form a whole of a new order; but if some salts increase whilst others diminish the coloring power of this root, these are phenomena which still remain unexplained. If all the salts behaved in the same manner, and all formed an obstacle to the dyeing, one would see in this fact the natural consequence of a very general property in all the coloring matters, namely, that of becoming less soluble in waters charged with saline matters than in pure water; but, as this is not the case, it is better to avow ignorance on this subject than to lose one's self in the region of hypotheses.

Maddering is performed sometimes in one operation, sometimes in two. But the dyer having the greatest interest in getting his dyeings performed at one operation, never divides them into two except in particular cases. It has been stated, that regard should be had to the proportions of water employed for dyeing; in other terms, that a certain relation must exist between the water and the madder: now, as on the one hand the vessels in which the dyeing is performed are of a determinate capacity, and as, on the other, certain kinds of printing require an infinitely stronger proportion of madder than others, it is obvious that it would be difficult to dye in one operation stuffs which require high proportions of madder, for not only, in consequence of not observing the proportion between the water and this substance, one would be liable to lose a very great quantity of coloring matter, but further, this coloring matter not penetrating the stuff with sufficient uniformity, would give only shades more or less unequal.

Other considerations may likewise place the dyer under the necessity of proceeding by a double maddering. It has been remarked, that the colors always lose their vivacity when their mordants are supersaturated with madder; so, to obviate this disadvantage, the dyeing is usually performed in the first place with the quantities either just necessary, or rather too weak than too strong, of this substance; then, the maddering being finished, if the mordants are not saturated, a new dyeing is proceeded with, to give them the quantity of coloring matter in which they are wanting.

For the good execution of several kinds of work, it is indispensable to make sure of the perfect saturation of the mordants dyed in madder, especially for that of the colors which must stand clearings, or which are destined to pass into new dye-baths. If, for example, it is desired to re-enter mordants of iron or alumina on a white maddered ground, to be subsequently dyed in quercitron, then, if the original madder-dyed mordants are not perfectly saturated with coloring matter, the reds and violets, by attracting the yellow matter, pass, the former to orange or to a dull red tint, the latter to olive-grey. It may be known by several signs if a mordant is not saturated; first, by the appearance of the bath, which becomes clear or *poor* when it is exhausted; but this mark is not very precise: next, by the confusion of the different kinds of red, which are well defined only when the mordants are saturated; lastly, by the readiness with which these same colors pass to a yellowish tint on the meadow.

By associating with the madder other coloring matters, compound hues are obtained. There is, for example, a yellow coloring matter which, by acting concurrently with that of the madder, produces on the mordants of alumina, tints which tend more or less to orange-red and even to orange-yellow, according to the proportions; and on the mordants of iron and alumina very different shades, from wood and cinnamon colors to the deepest bronzes, according to the relative quantities of the iron and alumina mordants on the one hand, and the tinctorial matters on the other.

In the dyeing of those colors compounded of madder and other substances, the affinity of which for the mordants is not the same, it is necessary to take care either to employ the exact quantity of madder, if one wishes to mix together all the substances which must go to the formation of a color, or else to dye in two operations, and according to the shade which is wished to be given to the color, or to begin with the madder shade, to be afterwards passed into the bath of yellow coloring matter, or else to pass the stuff into the yellow bath, and from being saturated with this, to dip it then in the madder, with the precaution of stopping when the latter, by displacing a sufficient quantity of yellow coloring matter, shall have created the desired effect.

It results from all which has been said on the subject of maddering, that every printer should attend to the following rules:—

First, Take care to print only goods perfectly bleached and free from fatty bodies; otherwise the impurities of the stuff attract the mordants during the dunging, and at the dyeing fix coloring matter which alters either the printed parts, or those which should remain blank. Second, Observe that the fixing or dunging be as perfect as possible, especially in a madder dyeing—for with quercitron or some other dyes, this is less important—as well as the complementary washing operations. The printer will know that these operations have been well performed when, on rubbing a part of the stuff with the nail, nothing comes off, and on wringing the same part, the water which passes from it is perfectly clear. Third, Pay attention to gradually elevate the dye-baths, and never let them fall to be raised again. Fourth, Proportion the water made use of, to the quantity of madder employed, keeping in view the quality of the madder and nature of the solvent. Fifth, Ascertain the degrees of temperature which best suit the shades he wishes to produce, some of which can only be obtained at low, others at much higher temperatures, and not to forget that, all other circumstances being equal, the maddered shades are duller and the white parts of the stuff more stained in proportion as the dyeing has been performed at a higher heat; that by prolonging the duration of a dyeing, the same effect is produced as by raising the temperature to extract from the madder all its coloring principle; that under 70° there is no dyeing effect, and that the coloring matter produces its best effect between 100° and 140°. Sixth, Use as far as possible pure waters, which, besides the economy in madder which they procure, offer further the immense advantage of charging but slightly the blank parts of the stuff, which, not being covered with mordant, should remain in their natural state; or, if he is under the necessity of employing waters that are impure and loaded with saline matters, he must correct them, not only with the view of obtaining more considerable returns, but likewise that they may injure as little as possible the parts of the stuff which are to remain blank, for what would be the good of shades full and bright after the dyeing, if they should be degraded by the numerous operations and the more or less powerful agents which it would be necessary to employ to bring back the blank parts of the stuff to their original purity? Seventh, Not to forget that every dyeing with madder does not give rise to bright and fast shades, capable of standing the operations of clearing, except in so far as it is performed in presence of a certain quantity of chalk; consequently, that the dyeings which might be done with Alsace madders and pure water could not be submitted to these operations. Eighth, To proportion the quantity of madder to the quality and strength of the mordants deposited on the stuff, knowing that not only is there a loss in employing the madder in excess, but further, that the colors obtained under the influence of this excess are always dull.

5th, Clearing.—On coming out of the madder-bath, the colors are far from having the lustre, liveliness, and purity of those shades which are so much admired; they must first undergo several operations essential and indispensable to free them from the foreign matters which accompany them, and to acquire, along with these qualities, the fastness or durability of which they possess so little beforehand, that a short exposure to the sun would be sufficient to alter them. This effect, which adds at the same time to their lustre, is due to the soap.

It may here be remarked that the violet mordants, compared with those of alumina, present a peculiarity which must not be passed over in silence: when they are immersed in a dye-bath, they acquire directly the purest shade, so that, if they become dull, it is only by the deposit which is formed on the whole stuff, and which alters the white as well as the dyed parts of it; it may therefore be assumed, that if it were possible to preserve all its purity to the stuff during the dyeing, the finest violet shades would be the immediate consequence of that operation. The red mordants, on the contrary, whatever precautions be taken, and at whatever period in the dyeing they be examined, have always a brick or brownish orange shade more or less decided; they differ, therefore, from the violets in respect that the colors which they produce require to be cleared and fixed, whilst the violets demand only, so to speak, the operations necessary to fix them.

It is not very long since a perfect ignorance existed as to the essential object of the operations which follow the dyeing, and which are about to be passed in review. No other purpose was assigned to them but that of bringing back to their primitive state the blank parts of the stuff stained by the dyeing; it was far from being suspected that it is to these operations that the colors produced by the madder owe their stability, and particularly that the agent—soap—which is specially used to test the fixity of a color, in consequence of the powerful action which it exerts upon it, is precisely the body which gives the greatest stability to the tinctorial matter. It is not surprising, therefore, that not having settled views on this point, printers did not know the most suitable substance to employ, and that they could find no better name to give to those important operations than that of the *bleaching of maddered stuffs.*

At the end of the last century, the goods, on coming out of the maddering, and after being washed, were exposed for weeks on the field to the action of the air and the sun's rays, and watered from time to time. When they began to bleach, and their colors to get weak, they were taken up again to be boiled in a water holding in suspension a certain quantity of dung or of bran. This operation had for its object to accelerate the decoloration of the stuff, and by reducing the number of the days of exposure on the field, to diminish the unfavorable risks inseparable from this kind of bleaching.

Delormois, who visited several dye-works in Holland and Switzerland, and who wrote an excellent little volume, entitled, *The Art of Calico Printing*, Paris, 1786; Scheffer, in 1787, and Berthollet, in 1804, point out no other processes. So little at that time were the effects which soap produces in such circumstances suspected, that, in the second edition of Scheffer, published in 1803, it is said: *Soap-water weakens and destroys the fastest madder color, that even of Turkey-red; whence it follows that soap must be used as sparingly as possible in washing cottons which have this color.*

The unpublished notes of M. Daniel Kœchlin, however, which date from 1804, prove that at that time soap was beginning to be employed for this purpose. In his establishment the process followed was this:—The goods, rinsed and perfectly washed on coming out from the maddering, underwent, before being exposed on the meadow, two successive clearings in a bath of soap and bran, which was composed for twelve pieces, representing about two hundred and twenty yards of cloth, by adding to the boiler filled with water—

For the first clearing 4·5 pounds of soap and ·25 bushel of bran.
" second " 2·2 " "

When the baths were in full ebullition, the goods were immersed in them, and circulated by a wince, keeping them at this temperature during thirty to forty minutes. Rinsed and perfectly scoured after each wincing, they were then carried to the field, where they remained exposed from five to eight days, according to the season and state of the atmosphere. They were then taken up to be subjected to a new wincing in a soap-bath at ebullition, and formed this time of two pounds of soap and one gallon of bran. After washing and scouring as before, they were exposed again on the meadow during seven days, subjected to a fourth wincing in soap exactly the same as the last, and then, according to their state, they were put back on the meadow three, four, or six days. The fourth part of the goods, at most, were thus completely bleached; those which remained underwent a fifth wincing, and a new exposure of seven days on the meadow.

Having recited the old methods, the Editor will proceed, in the first place, to give a condensed statement of the operations of clearing, such as they are now performed, and will then endeavor to explain the action of the agents which are used.

The operation of *clearing*—a name which designates the process by which the maddered colors are brightened and fixed—is performed in the same kind of *becks* as those which are used for the maddering, and in a dye-work there are always some of these vessels specially devoted to this operation. To the volume of water necessary to cover the goods, quantities of soap are added proportional to that of the color with which the stuff is covered, but not losing sight of the fact, that colors with a base of alumina require generally a larger portion of this saline compound.

When the goods have been withdrawn from the madder-bath, they are placed, after being perfectly washed and scoured, in a beck filled with a solution of soap, as if it were intended to dye them anew, and are made to circulate, mechanically if common goods, by hand if they are muslins, book muslins, *et cetera.* The operation is usually commenced at the temperature of 65° or 70°, which is progressively raised to the degree of heat which fixes and determines, at the time of this first wincing, the nature of the shade which it is desired to obtain. This is an essential point; if it be neglected, all the precautions which have been taken in the preceding operations to obtain pure and delicate dyes become useless. An example will make this better understood.

If a stuff mordanted for bright rose-color has been maddered, and it has been dyed at a low temperature, by passing it into soap at 100° for one hour, the desired shade will be arrived at by immersions in acid, and soap-baths subsequently given; on the contrary, the printer will never succeed if he has had the imprudence to give the first wincing at the temperature of 170° or 180°, much less if at 212°, unless, as HAUSSMANN advanced, the stuff has been previously treated with pure water heated at high pressure in a close boiler. The reason of this difference is, that the wincing in soap has the effect of fixing the coloring matter, and of rendering it infinitely less easily acted on by the agents, and that this fixation is so much the more energetic as the temperature is more elevated. Nevertheless, this observation applies only to colors with a base of alumina; if, therefore, goods dyed in violet are to be cleared with soap, one may without disadvantage submit them to the action of the soap at a high temperature, since the violet requires, as has been stated, only to be fixed.

As regards the duration of the operation, experience proves that it is useless, if not hurtful, to prolong it beyond one hour.

During the circulation of the goods in the soap-bath, the latter changes its nature, and modifies the colors with which they are covered; the coloring matter which sullies the white of the stuff, is fixed upon it by the lime, as has been proved by direct experiments; there is then formation of insoluble oleate, stearate, and margarate of lime; at the same time the coloring matter enters into solution in the bath, and the white parts of the stuff are purified, unless their coloration be due to portions of oxides which might be diffused in the dung-bath during the operation of dunging, and which, by fixing on the stuff like mordants, might have attracted the dye. On the other hand, the colored parts becoming deprived of the color which is not intimately fixed, and of that which is not to form part of the lake, the soap-bath contracts a pretty deep red hue, and is found in many cases so rich in tinctorial matter that one may dye certain styles by it with advantage.

Besides that the bath gets charged with color, it further undergoes a change which affords a key to the part which the soap performs. In the beginning it is frothy, but by degrees, and in proportion as it is longer in contact with the goods and the temperature rises, it loses this foamy appearance, as if all the fatty substance were taken from it by the stuff, and becomes thin. In this state the gross color has gone down, and that which is in solution is very pure, and now re-dyes and feeds the mordanted part. Whilst a new soap-bath scours and reduces, many inferior lilacs are cured by wincing in this kind of spent soap-bath. If then left to cool, it forms a deposit of fatty acid and coloring matter, united with lime, and the clear liquor from which this deposit is produced no longer contains fatty bodies in solution, since it is not rendered sensibly turbid by the acids.

The proof that this passage in soap has not only the result of bringing back to white the parts soiled by the dyeing, and of depriving the lake of the impurities which accompany it, is, that the colors so treated now resist infinitely better the destructive influence of the light, and of different agents, as chlorine and the acids.

Sometimes, immediately after scouring and cleaning the goods, they are given a second wincing in soap; but one never goes further than this, because experience has shown that it is in vain, even by augmenting the proportion of soap, to try to fix in this manner a greater quantity of fatty bodies; the only result would be a weakening of the colors, and by no means a clearing in any proportion to the agent employed.

After this first action of the soap, it is necessary, in order that the colors may be able to assimilate a greater quantity of fatty substance, and acquire more lustre and fixity, that they should undergo the influence of the air, or of chlorine, or of acids; but all kinds of work do not equally stand the intervention of these different agents: thus, very delicate cylinder printings will scarcely admit of exposure to the air, whilst they agree better with acids or acid salts; on the contrary, stuffs on which there are several reds, especially deep reds, containing a strong proportion of mordant, are treated in preference by the air, seeing that the acids to the action of which they would be submitted, by taking away a portion of the base from the different shades of a pattern, would degrade them to the extent of making those distinctions disappear which one has so much interest in preserving between them.

By exposure to the atmosphere, the goods become of a purer white, but they soon contract an odor of rancidity, more or less analogous to that exhaled by oiled cloths, and the colors which at first become more lively are not long in changing; the reds turn to orange, and the violets to grey. It is for the dyer, who ought to know the maximum effect to realize during the first exposure, to stop in time enough not to compromise his success.

When acids are applied instead of air, the operation is performed in a beck surmounted by a reel, and containing water acidulated either with nitric acid, sulphuric acid, or chloride of tin; the latter—technically termed *stannic soap*—is only used for pink reds, and not for iron mordants. The quantity and proportion of these acids vary with the kinds of printing and the shades desired. Formerly, a mixture of soap and salt of tin was used, but soon perceiving that, at bottom, this preparation acted only by the acid which it contained, printers replaced it, for greater economy, by the nitric acid, and, better still, by sulphuric acid. Nevertheless, the stannic compound gives rise, in certain cases, to secondary effects which must not be overlooked; thus, when the colors are very readily acted on by the acid, there may be deposited in the blank parts of the stuff a portion which becomes fixed and stains them, and in this case the soap, which acts physically, prevents the evil by seizing on the color. On the other hand, the stannic compound often determines a displacement and a true substitution, which has for its result to introduce into the lake a certain quantity of tin which modifies its shade; but again, and lastly, its action, which is always less powerful, permits of brightening, in addition to reds, such colors as blacks and violets, on which the acids exert a too marked influence.

Whatever be the reason, there are cases in which treatments with even very powerful acids are always preferable to those with soap of tin: this happens when the color, after being already fixed and submitted to the solution of tin and bran, is very deep and presents a great resistance.

The goods should be circulated in the acid-bath till the colors undergo the desired modifications—till the reds, for example, turn orange-red, and the roses orange. This modification of the maddered color is produced the more easily, the lower the temperature at which this color has received the first soap, or, in other words, with greater difficulty the more it is saturated with soap, and especially if it has undergone a long exposure to the air. Thus, all other circumstances being equal, two colors of the same shade and tone will be equally modified by an acid of the same kind and strength, only in so far as they shall have fixed the same quantity of soap, and been submitted to the action of the air during the same space of time.

The acid water into which the goods are thus passed contains a pretty strong proportion of coloring matter, which always tinges it an orange-yellow. The proportion of this coloring matter is so much the greater as one makes use of an acid more or less concentrated, and in proportion as the goods passed into acid were covered with deeper shades, that is to say, colors richer in mordant.

After exposing the goods to the air, or passing them into an acid-bath, they are immediately thrown into a new soap-bath, similar to that already described, which has for effect to render the hues more lively and stable.

A second exposure to the air, or a second wincing in acid, and a third in soap, are often indispensable; sometimes one is even obliged to multiply the number of these operations, according to the process which one follows; but this is not the point to be discussed at present: suffice it to say that, at bottom, these operations are always the same, but that sometimes the high temperature of the last soap-baths having no longer the same influence on the shades, it becomes necessary to give these baths in a close boiler at the pressure of four atmospheres.

In these different circumstances, and especially when the last immersion is performed in a close boiler, the coloring matter of the madder undergoes a true modification, somewhat analogous to that which is produced on it by a long exposure to the air in the course of treatments with soap; it is difficult, at least, to admit the contrary in presence of the following facts:—When the printed goods, on coming from the maddering, are passed into an acid-bath, whatever be, so to speak, the degree of dilution of this bath, the colors with which they are covered are immediately modified; the reds pass to orange, and the violets to a dirty olive tint. If at the instant when these colors are so modified, one proceeds to immerse the stuff which is covered with them in a milk of lime, all the tints—red, rose, violet, lilac, and black—pass immediately to the most lively violaceous blue, but more or less intense, and preserve momentarily this shade. Now, if one repeats this operation on the same goods covered with the same colors, especially after they have undergone all the operations of clearing, and the last passage in soap has been given at a high temperature in the close boiler, one finds that the acid which at the beginning exerted so lively an action upon it, no longer produces any effect, and that the lime is no longer capable of turning to blue the portions which the acid has touched. This experiment is so plain, that by observing, watch in hand, the duration of the contact with the acid, one may follow perfectly the progress of the clearing by the greater and greater resistance which the colors oppose to the action of the acids, and consequently of the lime.

From these facts it is natural to ask, whether the coloring matter, brought to this point of fixation, is identical with what it was at the moment when it combined with the mordant? One of two things must hold: either the mordants are modified, and become of such a nature as not to be acted on by the acids, and hence no displacement can take place, or else they experience only an insensible modification, and it is the coloring matter which is metamorphosed. The former of these suppositions is not without some appearance of truth; it results from many scattered facts, that the oxides which here play the part of mordants, and even their basic saline compounds, are modified with the greatest readiness by the action of heat; but the second hypothesis is perhaps better founded. It has been ascertained by direct experiments, that the coloring principle of the madder does not combine purely and simply with the sesquioxide of iron, as one is generally led to assume; but that this oxide, which is formed ultimately on the cloth after the operations of printing and fixing the mordants, by yielding a portion of its oxygen to the coloring matter, oxidizes it, and then passes to an inferior degree of oxidation. If it were not so, one would have difficulty in explaining how lilac, violet, and black could result from the combination of the oxide or rust color, more or less deep, with a matter which, in its present state of isolation, has a weak orange-red tint.

According to this opinion, based on the reduction of the sesquioxide of iron, the red tints obtained from the madder would be formed in other conditions than the violet tints; the coloring matter would not be in the same state. Now, does one not arrive at this result by studying the dyeing of the mordants during the maddering? Do not the violet colors take, of themselves, without the co-operation of intermediaries, the purest tints, while the reds acquire only a brown shade, quite different from that which they contract at last after the wincings in soap, and especially by the exposures to the air, or the treatments with chlorine or with acids? Is it not natural, therefore, to think that these operations have chiefly as their effect to determine the chemical changes which give to the coloring matter properties it does not possess, either in its state of isolation or in its original combination with the mordant? It is to no purpose to allege, that in the maddering the red matter exists ready formed, but that its combinations are soiled by the foreign bodies which accompany it in the madder, and which the clearing must take away from it; for, without absolutely disallowing the partial effect of these foreign bodies in the determination of the fundamental shade, it will be sufficient to recall the fact, that the purest coloring matter, that which is disengaged from the brightened Turkey-reds and violets or rose-colors, furnishes precisely the same tints as the madder, and that it is indispensable to submit these tints to the operations of clearing to give them all their brilliance.

Having now explained the operation of the clearing in its details, and the effects which it produces, a few remarks will be made on the substances required in the operation.

Abstracting the influence which the waters may exercise on this process by the nature of the salts which they contain, one can understand without difficulty how, in an economical point of view, it is important to the dyer or printer to use pure water, since otherwise he is obliged to employ in mere loss a great quantity of soap for the decomposition of the calcareous salts. If, therefore, he is constrained to use water of this nature, he will require to remove its bases by suitable portions of carbonate of soda, or caustic soda, according as they shall be charged or not with bicarbonate, in order to transform the salts of lime and magnesia into insoluble carbonates. The corresponding salts of soda which take their rise from the double decomposition, have no injurious action on waters so purified; nevertheless, the soda should never be employed in excess, and, consequently, if, by any cause whatever, it came to predominate in the liquid, it would be necessary to saturate it with a corresponding quantity of sulphuric acid.

It is a point on which dyers are generally agreed, that one should not use an alkaline soap for the first immersions; on the one hand, the alkaline bases, having a strong tendency to dissolve the alumina—the base of the red mordants—such mordants, saturated with coloring matters, always give way on passing into baths of alkaline soap, and leave there a portion of their oxide. On the other hand, this excess of alkali becomes an obstacle to the realization of the most important effect of the operation, that of fixing the fatty body. The soap, in fact, when it is neutral, undergoes a decomposition under the influence of a great quantity of water; the base and the fatty acids then separate, to pass into two new salts—an alkaline salt which remains in solution, and an acid one which is set at liberty, and gives to the water a milky appearance; in a word, it is the same phenomenon as that which is produced by a liberal addition of distilled water to a transparent solution of soap; the latter gets clouded, and deposits at length two insoluble bi-salts. It is by reason of the formation of these that the colors become saturated with fatty bodies, seizing by their bases—and the lime might here play an important part—the excess of fatty acid to form a neutral soap, which is destroyed in its turn, till the liquor, becoming too alkaline, is no longer decomposable either by water or by the colored lake. To endeavor to prevent the formation of these bi-salts, by employing either an alkaline soap, which is less liable to undergo the kind of decomposition which has just been referred to, or concentrated saponaceous solutions which are not less so, would be to defeat the very end proposed. The necessity of making use of soap free from alkali is so strongly felt, that compounds of this nature are always rejected for clearings, or they are used only by adding, either directly or indirectly, a certain quantity of fatty body; thus, certain dyers supersaturate a solution of soap with oleic acid, for example, which proceeds from the fabrication of wax lights, or, in default of the latter, add sulphuric acid to this solution, heated, till the fatty acids, which precipitate and reenter into solution under the influence of the excess of alkali, cease to redissolve.

The necessity of employing a neutral soap is dispensed with for the last immersions, seeing that for most kinds of work a certain quantity of carbonate of soda is commonly added to the bath.

M. E. SCHWARTZ alleges that all the fatty bodies are not fitted for the making of soaps suitable for the clearing of maddered colors, and especially those that have been treated with chlorine or with nitric acid.

It will be impossible to enter here into any detail on the nature of the acids, or the kind and proportion of that which it is best to employ in particular cases. It may be stated, however, that if all of them lead to the same final result, that is to say, to the purification of the colored lake which exists on the stuff, it is far from being the case that they all brighten the colors to the same degree; in this respect, the phosphoric acid is infinitely less trying to the mordants than the nitric and sulphuric acids.

The following general rules are given by PERSOZ for the guidance of the printer or dyer in the operations of clearing:—

First, That the different kinds of printing require a first wincing in soap at a set temperature for each of them, and that this first operation having for its object to fix the coloring matter, the dyes will take so much the more fixity in proportion as this temperature is higher; and that, if the color is not sufficiently modified at the moment of its being fixed, it will be extremely difficult, if not impossible, to clear it.

Second, That an exposure to the air or a passage in acid must always succeed that in soap, in order that the action of the latter may be efficacious in the subsequent immersions.

Third, That the colors acquire so much the more fixity in proportion as the fatty body accumulates on the stuff in greater quantity, up to certain limits, nevertheless, beyond which the soap is without effect.

Fourth, That the air does not exert the same action as the acids, and that the colors which have been exposed to its influence are always more solid and less jaded than the others.

Fifth, That it is not a matter of indifference to employ an acid of any kind or strength in the clearing; that the nature and proportions of this acid must be regulated according to the work under treatment, and according as the acid immersion succeeds or not to the first, the second, or the third wincing in soap.

Sixth, That the immersions in the close boiler with which the operations of heightening are often concluded, have for their object to determine the strongest degree of fixity of the colored lakes, and thus give, in many respects, the same result as a long exposure to the air, and to the influence of the luminous rays.

Clearing with Bran.—It has been shown that madder dyeings, performed in certain conditions, not only stand the action of soap, but further owe to this body, which possesses in a high degree the power of bringing back to their primitive state the unprinted parts of the stuff stained by the dye, their liveliness and their solidity. There are colors, however, such as those which are obtained from the Alsace madder in presence of pure water, and without the co-operation of chalk, from garancin, weld, quercitron, India wood, Brazil wood, cochineal, and some other dyes, which never experience the action of a soap-bath without their shades being either modified or greatly deteriorated. It is with the view of preventing these degradations of the tints, while clearing the colors and bleaching the ground, that after a dyeing the clearings with soap are in many cases substituted by immersions in bran, which have for their object to remove by boiling—along with the coloring substances with which the unmordanted parts of the stuff get loaded during the dyeing—the brownish matters which tarnish the shades of those parts that are mordanted. These immersions are given in the same manner and in the same apparatus as the soap-baths.

As the consumption of bran is now pretty considerable, especially in the execution of certain kinds of work, M. Daniel Kœchlin, with the view of regulating the expense, determined by a series of experiments the following points:—First, The quantity that is required of it for the treatment of a certain number of pieces; second, the temperature and duration of an immersion; third, the most suitable quantity of water for the operation; fourth, the kind and quality of bran to which the preference should be given; and fifth, which part of the bran, the soluble or insoluble part, produces the greatest effect.

All his operations were conducted in ordinary dyebecks, containing two hundred and twenty to two hundred and sixty gallons of water, on ten pieces of calico of common quality, forming a total of about three hundred and twenty yards in length, maddered two and a half hours, and five minutes' boiling.

To resolve the first question, ten pieces were boiled comparatively, and during one hour:—

1st, In pure water.
2nd, In water mixed with 14 pounds of bran.
3rd, „ „ 28 „
4th, „ „ 57 „

And it was found that the most suitable proportion of bran was twenty-eight pounds—that a less quantity did not give all the effect desired, that a stronger proportion was pure loss. To know whether, when strengthened with suitable additions of the same substance, an exhausted bran-bath was capable of giving the same results, ten new pieces were passed into each of the above baths, with a small proportion of bran added, and the colors, on coming out of this bath, were found as well cleared as those of the goods which had been passed into it in the first instance; the ground alone was not so pure.

To resolve the second question—the proper temperature and duration of an immersion—he passed the goods into three baths, each containing twenty-eight pounds of bran, brought to ebullition, namely:—

The first for	15	minutes.
The second for	30	„
The third for	60	„

Fifteen minutes sufficed to clear the white parts, but thirty minutes were necessary to give to the color all its fixity; beyond this limit there was no appreciable difference between the results obtained at thirty minutes and sixty minutes.

To determine the quantity of water strictly necessary for the operation, two experiments were made:—

The first on... 130 gallons of water and 28 pounds of bran.
The second on 260 „ „ „

The white ground of the pieces submitted to the action of these baths was found sensibly alike; if a very slight difference existed, it was in favor of the pieces which came out of the bath formed with the greatest body of water; nevertheless, M. Daniel Kœchlin pronounces in favor of the small proportion of this liquid, in consideration of the less expense in fuel which it requires.

To know the kind of bran which it is preferable to employ, ten new pieces were passed into three different baths brought up and kept seething during one hour:—

The first formed of 28 pounds of wheat bran.
The second „ „ rye bran.
The third „ „ barley bran.

From the result obtained, there was an unquestionable advantage in using wheat bran; the rye bran likewise exerts a sensible action; as for the barley bran, it produces no effect.

To decide whether coarse bran is more advantageous, ten new pieces were passed into three different baths, brought to ebullition and kept at this point during thirty minutes:—

The first formed of 28 pounds coarse bran, well cleaned.
The second „ 28 „ fine bran, very floury.
The third „ {28 „ dry bran.
4·4 „ flour.

The result of these three comparative experiments was in favor of the coarse bran; it was this which rendered the white ground purest, and cleaned the colors best.

Bran treated with boiling water separates into two parts, the one soluble in warm water, which includes the mucilage; the other insoluble, or straw properly so called.

An approximative analysis of the former gave, for one pound:—

	Pounds.
Portion soluble in warm water, formed chiefly of gluten, mucilage, and starch, a part of which precipitates on cooling	0·288
Portion insoluble in water,	0·576
Water and loss,	0·156

On trying comparatively the effect of these two distinct portions on the stuff, it was shown that neither the one nor the other, employed separately, acts so efficaciously as when they are united; the starch would appear to have no influence.

In certain localities, the bran is only employed when it has undergone a previous fermentation.

All kinds of dyeing cannot, like the shades obtained with madder, support the action of boiling bran; there are colors which are powerfully affected by this substance when at a high temperature. One should only use a decoction of bran, therefore, after having brought it to the degree of heat at which the immersion may be made without danger, while obtaining as directly as possible the bleaching of the ground; or else, if the bath is kept at a temperature near ebullition, leave the goods only just the time necessary to clear the white. A fact which must not be lost sight of, and on which M. DANIEL KŒCHLIN is careful to insist, is, that the action of the bran is exerted in an inverse ratio to the temperature at which the dyeing has been performed; thus it would be useless to pass goods into bran water at the temperature of 100°, when the dyeing was performed at ebullition. Lastly, the action of the bran appears to increase with the temperature, for, if maddered pieces be submitted to the action of a bran-bath, under the influence of a high pressure, the white comes out from it perfectly pure, and the colors, especially the violets, acquire a much greater liveliness.

There are some who, in place of wincing in soap or in bran alone, to clear their colors, proceed by alternate immersions in these two substances, or employ baths composed of bran and soap together, alleging that the colors thus acquire greater lustre, are less jaded, and that the white is purer. It must not be forgotten that in this operation the fatty body is indispensable to the stability of the maddered colors, and that the bran does not contain enough of fat to give to the lake the degree of solidity which is necessary to it. The necessity of adding to it a certain quantity of soap is so fully recognised, that to give to the maddered reds and roses all the brilliancy of Turkey-reds, the goods are submitted in some establishments to the following treatment:—After dyeing in madder, they are passed into bran to clear the colors; they are then worked at two different operations in *white liquor*—See TURKEY-RED in this article—dried each time at the temperature of 120° to 140°, and lastly cleared with soap and acid. Others arrive at the same result by a method quite opposite; that is to say, they pad the white stuffs in a soap-bath, dry them, and then print the mordants. The dunging is performed as usual; but it is important to clean well, that no portion of fatty matter may adhere to the unprinted parts.

In concluding this part of the subject, the following summary may be given of one of the best processes for clearing madder colors, when no sumach has been employed in the dyeing. The goods, having been previously well washed at the dash-wheel, are treated as follows:—1. Wince for half an hour in boiling bran-water. 2. Wince for half an hour or more in a dilute solution of chloroxide of sodium or calcium. 3. Boil the goods in soap-water, containing half a pound of soap per piece. 4. Wince a second time in the bleaching liquor, weaker than before. 5. Boil a second time in soap-water.

It will be observed that this process includes both soap and bran; but when the goods are dyed with Dutch madder and sumach, soap cannot be well employed in the clearing process; in that case only bran and chloroxide of calcium or sodium are used, the latter being preferred. If dyed with the form of madder called garancin, neither chloroxide of sodium nor of calcium is admissible.

When the goods have been subjected to the several processes of which the details have been given, namely, *printing*, *drying* and *ageing*, *dunging*, *dyeing*, and *clearing*, they are passed through the usual finishing operations as for bleached goods, and are then ready for the market.

Such is the series of operations practised in the madder style of printing, and which have been detailed at considerable length, because they are of greater importance and far more extensively practised than any other style—including, at the same time, a general and connected view of the principles of calico-printing. Some extensive establishments, indeed, confine themselves almost exclusively to the madder style; or rather, it may be said that, at most printing-houses, the other styles are practised as mere varieties, or constitute only an accessory part of the business. In some cases, as in resist and discharge work, they are engrafted upon the madder style, and form a part of it. This style, it must be remembered, includes not only the use of the dye-stuff from which it receives its name, although, by varying the printed mordants, a great variety of tints and shades from the most permanent blacks and the finest purples, to crimson and pale pink, may be produced with madder alone; it includes also the use of weld, quercitron, cochineal, and other soluble coloring matters, which give to this style of printing an almost unlimited applicability. The most expensive description of calico-printing, called chintz-work—a term descriptive of that kind of printing which is employed for window curtains and other furniture, and which differs so much in the richness and variety of the colors—is produced chiefly by the madder style; and this alone may give the reader an idea of the extent of the resources which it commands.

From these remarks it will be seen that the other styles, not including so many interesting processes and abstruse principles, do not require to be treated at the same length. A mere account of their distinguishing features will be sufficient, in a work which has chiefly for its object the elucidation of the chemical principles involved in the subjects discussed.

II. PADDING STYLE, *for Mineral Colors.*—Colors from metallic oxides are very elegantly applied by this style, either to produce simply a colored ground, or a design in a mineral tinctorial matter on a white or colored ground. When the object is to form a ground for the reception of a design in other colors, the entire surface of the cloth may be impregnated successively, by the padding machine, with the two solutions necessary to produce the color, or else the cloth may be padded in one of the solutions, and afterwards winced in the other. To produce a design, the cloth may be first padded with one of the mordants and then printed with the other, but it is usually first printed with one of the solutions, and then may be either padded or winced in the other.

The method of wincing has been described in treating of the madder style. The padding is performed in a tub or trough containing the mordant, through which the cloth is passed, and then the superfluous mordant is expressed between the rollers. The annexed engraving—Fig. 397—will convey a correct idea of the common *padding machine.* E, F, are two cylinders covered with blanket stuff, and fitting with their journals, *a*, *b*, in slots in an upright, fixed on the frame, A B D C. The cylinder, F, acts as a squeezing roller, and to the pressure which it exerts by its own weight is added that of a lever, *e f*, carrying the weight, *g*. The calico is first rolled around the cylinder, N, furnished with a counterweight, *o*, to stretch the cloth, and from this it passes over a widening roller, *m*, dips into the trough, G, under the roller, C, and afterwards rises over a bar, I, with diverging grooves, to proceed between the two cylinders, E, F, by which the excess of liquid is expressed. It is then wound on the roller, H, the journals of which, *h*, turn in slots in the moveable bars, *i*, *k*, which are guided by a groove in the quadrant, *l*. The lower roller, E, being put in connection with the mover, communicates its motion to the squeezing cylinder, F, which in its turn transmits it to the roller, H. The goods are unrolled from N by the traction exerted by the cylinders, E, F.

Fig. 397.

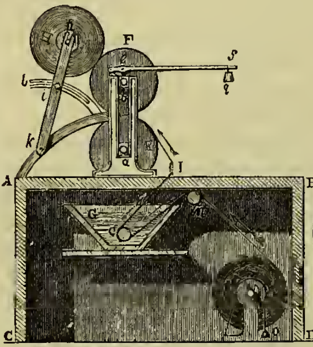
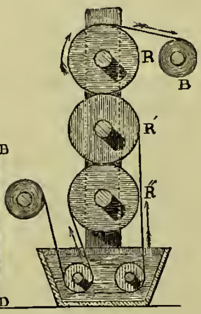


Fig. 398.

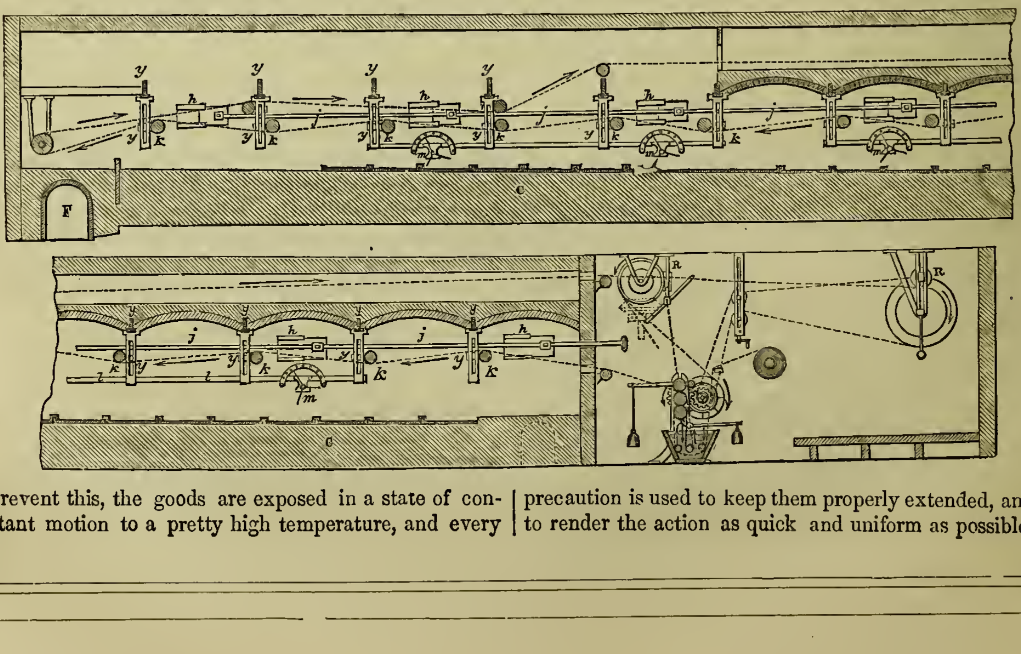


By this machine the cloth can only be passed once through the mordant, except by making the goods rollers change places, and repeating the process. By applying a third roller, however, the immersions and expressions may be given at one operation. This arrangement is represented in Fig. 398. Three cylinders, R, R′, R″, are placed one over another, and kept exactly parallel between the cheeks of a frame similar to that of a printing machine; pressure may also be applied to them by suitable levers. The calico, unrolling itself from A, dips into the mordant trough under the first roller, *n*, rises and passes between the cylinders, R″, R′, dips again into the mordant, and passing round the roller, *m*, is subjected to a second squeezing between the cylinders, R′, R, from which it proceeds to be taken up by B.

If the mordant or color is to be applied to the face of the cloth only, and not to both face and back, the cloth may be passed directly between two cylinders, the lower of which, and not the cloth, is made to dip into the trough; or the common printing machine with a roughened roller, and having the color doctor adjusted so as to allow a certain amount of color to pass, is sometimes substituted in this case for the padding machine. Whatever system be adopted, a perfect parallelism ought to be given to the rollers, to produce an equal pressure, and the speed must be so adjusted that the goods may have sufficient time to be properly impregnated with the liquid.

When padded, the goods are often left a few hours on the roller, to give time to the mordant to penetrate the pores uniformly. They are then dried quite hard by exposure to a temperature of 210° or 212°. This desiccation, indeed, constitutes a part of the padding process, which is not complete without it, and the thorough manner in which it is executed, is of the greatest importance. If not done quickly the whole operation will be a failure, whatever care may be taken in applying the color or mordant to the stuff, since the solutions employed for that purpose, being generally little thickened with gum, or not inspissated at all, will, if not speedily arrested, run or flow upon the goods, and accumulate unequally at different parts of the surface. A fold or crease in the goods, one part dried before another, a too rapid oxidation in some points—all produce centres of attraction which, instead of a plain uniform ground, yield one full of spots and inequalities of shade. To prevent this, the goods are exposed in a state of constant motion to a pretty high temperature, and every precaution is used to keep them properly extended, and to render the action as quick and uniform as possible.

Fig. 399.



For this purpose the goods may be circulated round a series of hollow cylinders heated with steam, as represented at page 317, in connection with the drying of starched goods. Indeed, the starching is simply a padding process; and the mechanism there described may be employed both for padding and drying. Or the goods may be dried in the hot-flue described at page 699. But another and better form of the flue, erected in some of the most extensive establishments, is represented in vertical section in the annexed engraving—Fig. 399.

The principle of this method is to circulate the goods over hollow rollers placed above heated iron plates. The apparatus consists essentially of a large vaulted flue, thirty yards in length, four in width, and three in height, cut in two, for nearly half its length, by six small vaults constructed in an opposite direction to that of the large flue. The object of these small vaults is to protect the large one from the too powerful action of the hot plates, and to prevent the dried goods, on arriving at the upper part, from coming into contact with the acids and moisture which are disengaged in great abundance, and might condense upon them.

C, C, is a long furnace, forming the bottom of the flue; the upper part is covered with iron plates, fitting one upon another, and capable of being brought to a red heat by the action of the flame which circulates under them. The thickness of these plates is not the same over their whole length; it goes on increasing from the point, C, to where they approach nearest the central source of the heat.

F is an arched passage, which gives access to the interior of this stove chamber.

h, h, are air-holes in the sides, opening and shutting at pleasure by means of the rod, *j*, fitted with as many valves as there are openings in the wall.

k, k, iron supports for rollers of tinned copper, which are fixed to the cross-pieces, *y, y*, and serve to conduct the cloth along.

l, l, iron bars for sustaining the ventilators, *m, m*, which are formed with wings of wire-work or metallic gauze, and make about three hundred revolutions per minute. Instead of placing these ventilators all at the same height, M. EDOUARD SCHWARTZ recommends to arrange them two above and two under the goods.

In front of the flue is exhibited all the mechanism required for the padding of the goods, and for communicating motion to them. This motion is conveyed by pulleys, R, R, which receive their impulse from a prime mover.

No one can doubt the superior advantage of this method of drying the goods, for, in their passage between the hot plates and the vault which radiates the heat, they are dried quickly, and all the better for the ventilators, which, by expelling the acetic acid and water, prevent their condensation. It is, therefore, generally adopted in England in large establishments, but is liable to the objection of being expensive in the construction. Of late, it has been slightly improved by substituting for the conducting rollers two endless bands, furnished with hooks, which travel by means of rollers or pulleys, and are kept extended by springs which stretch the piece in the direction of its breadth.

Processes.—Having described the apparatus for padding and drying, one or two processes may be given to illustrate this style of work.

To produce, for example, a *ground of prussian blue*, the goods may be first padded in a solution of acetate and sulphate of iron, made by adding three pounds of acetate of lead to a solution of four pounds of copperas in a gallon of water, then decanting the iron liquor from the precipitated sulphate of lead, and diluting to the density of 2° or 3° Twaddell. When the cloth has been padded in this solution, it is dried, and then winced in warm chalk-water; after which it is winced in a solution of a pound of yellow prussiate of potassa in forty gallons of warm water, to which are added four ounces of sulphuric acid. This gives a uniform ground of prussian blue.

To produce a *design or pattern* in the same color, the cloth is printed with the mixed solution of acetate and sulphate of iron, made as above, and marking 4° or 5° Twaddell, thickened with gum, and sightened with a little prussiate of potassa. After being aged, the cloth is winced in chalk-water, cleaned, and winced in a solution containing three or four ounces of prussiate of potassa and one fluid ounce of hydrochloric acid per piece, until it acquires the desired shade.

For a *ground of chrome-yellow*, pad in a solution of bichromate of potassa, containing eight ounces of the salt to the gallon of water; then dry with moderate heat, and pad in a solution of acetate or nitrate of lead, containing six or eight ounces in the gallon of water; wash and dry.

To obtain a *light lemon* tint, pad in a solution of acetate of lead of double the above strength, or sixteen ounces to the gallon, then wince the pieces through weak milk of lime; rinse; pad through bichromate of potassa; rinse and dry.

To obtain a *design in chrome-yellow*, the cloth may be printed in a solution containing from seven to ten ounces of acetate of lead, with the same quantity of nitrate of lead, to the gallon, and thickened with starch. After being printed and dried, the cloth is winced first in a weak solution of carbonate of soda, and afterwards in a solution of bichromate of potassa, containing about two ounces per piece. To clear the whites, the cloth may be winced in water slightly acidulated with hydrochloric acid.

Chrome-green is given by padding in a mixed solution of sulphate and acetate of copper, with a little glue, drying in the hot-flue, and next day padding in a caustic lie of specific gravity 1·05. The goods are then rinsed, and padded through a solution made with eight ounces of arsenious acid combined with four ounces of potassa, diluted with two gallons of water; then rinsed and dried as usual.

Iron buff or chamois, manganese bronze, chrome-orange, and other mineral colors, are applied in the same manner, either for grounds or designs. But the processes already given are sufficient to illustrate the principles of this style of calico-printing.

III. TOPICAL STYLE, *for Spirit and Steam Colors.*—Some vegetal dye-stuffs, such as indigo, annotta, and safflower, are either of themselves insoluble, or but slightly soluble in water, and therefore cannot be applied by the common maddering process. When these or their alkaline solutions are formed into a paste and printed on the stuff, some of them acquire a certain fixity by mere exposure to the air, others require that the stuff shall be previously imbued with a mordant, and others can only be fixed by subjecting them to the action of steam. In all these cases, however, the colors themselves, and not the mordants alone, are printed, or topically applied on the cloth, and hence the method of printing such colors is termed the *topical style.*

Spirit Colors.—All fugitive topical colors not fixed by steaming, are termed spirit or fancy colors. Properly speaking, however, the name is applied only to those colors produced by a mixture of vegetal dye-extracts, and solutions of tin, commonly called *spirits* by dyers. These all owe their vivacity, as well as the moderate degree of permanency they possess, to their tin mordant. After printing-on the topical color, the goods are dried at a gentle heat, and then merely require to be passed through the rinsing machine. This process is, therefore, much simpler than either of the two preceding styles. At the same time, the shades communicated in this manner have generally little permanence.

As a specimen of this mode of printing, the following recipe may be given for a *spirit purple.* A gallon of logwood liquor, of 6° Twaddell, is boiled for a few minutes with a pound of starch, and when the mixture is lukewarm a pint and quarter of solution of perchloride—nitro-muriate—of tin at 120° Twaddell is added, and then a quarter of a pint of oil. This mixture must be carefully stirred before applying it to the cloth, which, after being printed with it, is suspended for forty-eight hours in a warm room, and then merely washed at the rinsing machine.

A *spirit chocolate* is given by extract of Brazil-wood, extract of logwood, chloride of tin, and a little nitrate of copper—all mixed, thickened, and merely printed on. The thickening in this case may be either starch or British gum. But a faster chocolate is obtained by first printing on a mixture of logwood liquor, red liquor, and oxalic acid, and after ageing passing the cloth through a solution of bichromate of potassa—a process, however, which cannot properly be called topical printing.

A *spirit red* is obtained by extract of peachwood and tin, with a little nitrate of copper. For a good spirit pink, one gallon of peachwood liquor at 8° Twaddell, is boiled briskly with one and a quarter pound of starch; half a gill of solution of nitrate of copper at 100° Twaddell is then added, and when the mixture is cooled to about blood heat, three gills of solution of perchloride of tin, four ounces of *pink salt*—chloride of tin and ammonium—and one gill of oil are introduced.

Prussian-blue is prepared for topical printing by grinding it in a hand-mill, like that for grinding pepper or coffee, and triturating the powder with solution of chloride of tin; it is then thickened and printed on the stuff. To convert the prussian-blue into green, the goods, after rinsing, are passed through a solution of bichromate of potassa. Indigo communicates a faster blue, so far as the action of soap and alkalies are concerned, than prussian-blue; but the latter possesses considerably more brilliancy than the former in its ordinary state. As a topical color, indigo is applied in the form of indigotin, or the hydride of indigo-blue; the deoxidizing agent employed to produce the indigotin being either metallic tin, or the red sulphide of arsenic—red orpiment or red arsenic. *Pencil-blue* is prepared by mixing with water and boiling together about equal parts of ground indigo, orpiment, and quicklime, and when the mixture is withdrawn from the fire, and has become lukewarm, adding about the same quantity of carbonate of soda as of the other ingredients. The clear liquor, thickened with gum, was formerly applied or grounded-in with the pencil, and hence the name of the color. Till of late years, this was almost the only solution of indigo employed as a topical color; but a preparation, in which the deoxidizing agent is metallic tin, is now commonly substituted for pencil-blue, and is made as follows:—Four pounds of ground indigo are first intimately mixed with four quarts of water, to which are added two and a half quarts of solution of caustic soda of 70° Twaddell, with three pounds of granulated tin. This mixture is heated to the boiling point, then taken off and stirred until a drop placed on a glass plate appears of an orange-yellow color. To this liquor is afterwards added a mixture of a solution of chloride of tin at 120° Twaddell, with an equal measure of hydrochloric acid, until the free alkali is completely neutralized, and an olive-colored precipitate falls. The whole is then well stirred, and added to strong gum-water to the required shade.

Steam Colors.—This name is applied to topical colors printed in the ordinary manner, but fixed by steam. The application of steam to this purpose is quite a modern invention, and is one of the most important improvements in calico-printing. Very few colors attach themselves firmly to the cloth by being merely printed on together with the mordant; but by exposing the cloth so printed—with colors and mordants suitable for the purpose—to the action of steam, the coloring matter becomes attached to the tissues almost as strongly as in any other style of printing; combining, indeed, a degree of brilliancy with solidity of color, which can hardly be obtained in any other way, except by the madder process.

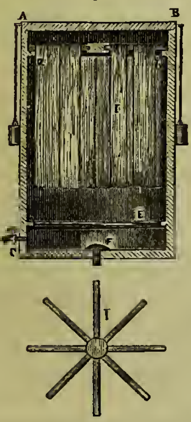
The first attempts which were made to render colors adherent by the application of steam, date from the end of the last century, and BANCROFT, in his work on Permanent Colors, published in 1797, states that he had succeeded in fixing the coloring matter of quercitron by this process. For many years, however, little attention was paid to the subject either in England or on the Continent; but in 1819 this new method of fixing colors was pretty extensively applied in France to woollen and silk goods. From that time it has extended, and is now universally practised by calico-printers on cotton and other fabrics with the best results.

A considerable variety of coloring substances admit of being fixed by this process; and some are directly applied to the goods without subjecting the latter to any preparation except bleaching; but the brilliancy and permanency of almost all steam colors are greatly increased by impregnating the cloth with a solution of tin, or for some styles with a solution of acetate of alumina, previous to the application of the colors. The salts of iron can only be applied in this preliminary process for a colored ground, as this kind of mordanting indelibly stains the fabric, and is therefore incompatible with printing upon a white ground. The solution of tin now commonly used is the stannate of potassa; and after being padded in the solution, the calico is usually passed through a cistern containing a solution of chloride of ammonium, to produce a precipitate of binoxide of tin. When acetate of alumina, or red liquor, is used, the goods are padded with it in the same manner, proportioning the strength of the liquor to the intensity of the shade which it is desired to obtain.

The goods should not be prepared in this manner too long in advance, especially with the tin mordant, which soon loses its property of fixing the colors. When so prepared for those colors which require it, the cloth is printed either by the cylinder or the block, with the mixed coloring materials and mordants properly thickened, or in some cases without the addition of any mordant but that which the stuff has already received. The calico, so printed, is dried in a warm moist atmosphere for a period of forty-eight hours, more or less. It is then ready to be exposed to the action of the steam.

Steaming apparatus.—There are five different forms of apparatus for steaming goods—the cask, the steam-chest, the lantern, the chamber, and the column.

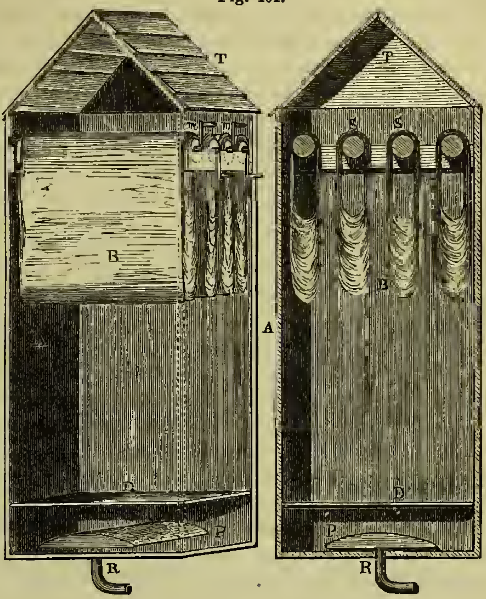
Fig. 400.



The simplest and oldest method of steaming is by the *cask* or *drum*, which is shown in vertical section in Fig. 400. It consists of a drum of white wood, B A C, the bottom of which is pierced with a hole to admit the steam-pipe, F, terminating in a rose. At three or four inches from the bottom is a canvas partition or diaphragm, E, intended to arrest any drops of water projected from F, and also to separate the condensed water from the goods. Near the upper part of the drum a hoop, *a b*, is fixed, which serves to support the frame, I, on which the goods are suspended to be exposed to the steam; and, lastly, a wooden head, or lid, is fixed on the drum, either by bolts, or by hooks of the form shown in the figure, to which weighted cords are suspended. Sometimes, however, instead of this wooden head, the utility of which is doubtful, the drum is closed with a cloth cover, which permits the air to escape at the commencement of the operation. The frame is studded with pin points, like that of the indigo vat; the goods are hung upon it in the ordinary way, and then wrapped round with flannel. The upper part of the frame must also be covered with flannel, to prevent the deposition of moisture upon it. At the bottom of the drum there is a stop-cock, C, to let off the condensed water. From twenty to thirty minutes is the average time allowed for one steaming operation.

The *steam chest* or *box* is another arrangement on the same principle, but more convenient for a large quantity of goods. It is shown in front and side view in Fig. 401. A is the chest, surmounted with its movable head, T; S, S, bobbins on which the goods are suspended, so as to form a kind of endless web, and which can be turned from without by the handles, M, M; D, the canvas diaphragm, or false bottom; R, steam-pipe fitted with a rose, P.

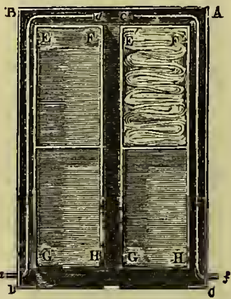
Fig. 401.



The *lantern* may be described by reference to the same figure. It consists of two parts—a movable box, which is properly termed the lantern, and a frame for suspending the goods. The movable box is similar in form to that represented in the last figure, having the same sloping roof to facilitate the trickling down of the water; but is constructed of copper, and is open below, so as to admit of being lowered from the roof by pulleys over the frame. The latter consists of spars of wood mortised together, and is formed like the skeleton of a four-legged table, strengthened with cross bars. Hooks are fixed on two of the opposite sides of this frame, and to these hooks the goods are suspended, so as to cross and recross the frame in zig-zag order. The latter, when filled with goods, and covered with flannels all round, is placed on a fixed table, through the middle of which an aperture is made to admit the steam-pipe; and immediately over the orifice of the pipe is placed a copper disc to spread the steam. When all is ready, the lantern is let down from above over the frame, and its lower part fits exactly into grooves made in the table, which can be stuffed steam-tight with lists of cloth. The steam is then let on, and when all the air has escaped through a small orifice formed in the lantern for that purpose, and nothing but steam is discharged, the orifice is stopped with a cork. The steaming is then continued from thirty to forty or forty-five minutes, according to circumstances; after which the penthouse is drawn up, and the goods are removed and spread out for airing. The height of the sides of the lantern, not including the sloping roof, is four or five feet, and the interior dimensions are six feet by four.

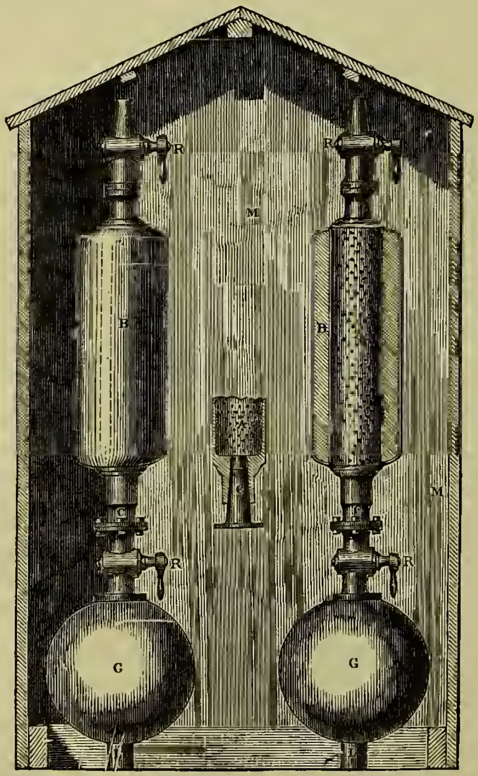
The *chamber*, which is represented in Fig. 402, is an apartment nine feet high, twelve in length, and nine in breadth, fitted with two doors in front, which are made of strong planks, shut by sliding in slots, and secured by strong iron bars and pressure screws. The steam is introduced into this chamber by two pipes, *a b c*, *d e f*, which are shut at the ends *c* and *d*, but are perforated along their sides with small holes to diffuse the steam through the chamber. The goods are suspended on two frames, E F H G, E′ F′ H′ G′, which are movable, and run upon rollers, so as to admit of being drawn out through the doors. The sides of the frame are provided with hooks for hanging the pieces in the zig-zag manner represented in the figure, so that in a chamber of the dimensions above stated, with frames to correspond, from six to seven hundred yards of cloth may be steamed at one operation. There is a safety-valve in the upper part of the chamber to prevent accidents.

Fig. 402.



The preceding forms of apparatus are chiefly used for steaming silks and woollens. For steaming calicoes the *column* is generally used. Two of these columns, the one in elevation, the other in partial section, to show the internal construction, are represented by Fig. 403, enclosed in a kind of lantern or penthouse. They are hollow cylinders of copper, A, from three to five inches in diameter, and about forty-four inches long, perforated over the surface with small holes, and terminating at their lower ends in a pipe, C. This pipe is made with a conical orifice, in which the tube from the boiler exactly fits. The latter is mounted with a stop-cock, R, to regulate the admission of steam; and, as it often happened that, at the moment of opening the stop-cock, water was forced into the cylinder with the steam, the improvement has been introduced of carrying the steam-pipe, L, into boxes or hollow spheres of copper, G, which receive the condensed water before it reaches the stop-cock.

Fig. 403.



In proceeding to steam the printed goods with this apparatus, the cylinder, A, is first lapped round with a few coils of blanket, then with several coils of white calico, next with the printed goods stitched end to end, and, lastly, with an outward covering of white calico, B. To perform this operation more easily, the cylinder is placed in a horizontal frame, in which it is made to revolve in winding the different stuffs upon it. The external envelope, B, is firmly secured with a cord at both ends, and the cylinder with its terminal tube, C, is then fixed upright upon the steam-pipe. The stop-cock, R, is now opened, then the lower stop-cock, and when the air has been driven out from the cylinder, and nothing but steam passes, the upper stop-cock is shut. The steam, having then no other means of escape, passes through the holes in the cylinder, and forces its way through the goods. If the latter were placed in immediate contact with the cylinder, the inner folds would be found to contract a different shade from the rest, and if the external covering were omitted, the outer folds would be very imperfectly steamed, besides being exposed to the danger of the steam condensing upon them. As a further security against this, the use of a lantern or penthouse, M, has been introduced, by which the column is protected from currents of air, and within which a number of such columns may be erected and put in operation at the same time. When the steam is shut off, the goods are immediately uncoiled, to prevent the risk of condensation, which is apt to make the colors run. If the operation has been properly performed, the unrolled pieces are found to be almost free from damp, and require only an exposure of a few minutes in the air to appear perfectly dry.

The action of the steam, applied by any of these methods, in fixing the printed colors on the stuff, is a question involving much interest. Does it produce its effect simply as a calorific agent, or in some other capacity? To determine this point, **Edouard Schwartz** divided into two portions a piece of woollen stuff printed with different colors; and over one of these pieces, while the colors were still moist, he passed immediately an ironing block heated to 212°. In these circumstances he found that the colors were perfectly fixed by the combined action of the moisture of the color and the heat derived from the iron. The other piece was subjected to the same treatment after the colors had been thoroughly desiccated, and it was found that in this case they were not rendered adherent, but could be detached from the stuff by the slightest washing.

PERSOZ justly remarks that this necessity for the presence of a certain quantity of water, to render the steaming effective, is very easily accounted for, since in this operation chemical reactions take place, for which the intervention of water is as indispensable as in the decomposition of sulphate of lead by sulphide of hydrogen. It is known that this gas, which attacks and sulphurizes the sulphate of lead with so much energy in presence of moisture, has, on the contrary, no action upon it in the dry state. Many other examples might be cited of double decompositions between the salts, which can only take place in the same conditions; but at present it may be sufficient to mention two phenomena which happen to be intimately connected with the steaming of colors. The chloride of sodium and silicic acid, brought into contact in the dry state, do not react upon each other; whereas, when water is present, silicate of soda is formed with disengagement of hydrochloric acid. The same chloride in a dry state, and concentrated sulphuric acid, react on each other very slightly; but in presence of a certain quantity of water they may be perfectly decomposed, even at a much lower temperature. Now, it will be found that steam colors are composed of bodies of this description, the reactions of which depend on the presence or absence of water.

The necessity of moisture to that effect which is produced by the steaming of colors, may be familiarly illustrated by the fact, that *dry chlorine gas has no bleaching effect upon goods*, and that it requires the presence of a certain quantity of water or moisture, with the hydrogen of which it combines, while the oxygen is set free to act upon the coloring matters.

But if water is essential, what is the best kind of steam to apply in this operation? Should it be a dry vapor, or steam charged with a considerable amount of water in the globular state, as happens when the supply is feeble or external condensation occurs? It is evident that, if both the colors and the steam are very dry, there will not be sufficient moisture present to produce the necessary reactions; whereas, if too much humidity is present, the colors will run, the pattern will be disfigured, and the shades confused, or the white parts of the stuff will be stained. These considerations involve others—how long the steaming should be kept up—the hygrometrical or drying nature of the colors—the exposure of the goods, after being printed, in a dry or moist place—how long the goods should be so exposed before steaming; and, lastly, the best kind of steaming apparatus to employ in particular cases? To assist the printer in determining these points for himself, according to circumstances, all that can be here attempted is to offer a few general considerations.

With regard to the influence of dry or moist steam, and the time of prolonging the operation, the printer must consider the state of the printed goods, with regard to their humidity, and whether or not they contain bodies capable of fixing a certain quantity of water. To produce clean and well-defined figures, it is advantageous to print with drying colors, but such colors steamed dry under considerable pressure will not be properly fixed, except by exposing them to a prolonged action; and this action, if too long continued, will cause the colors to run. Hence the difficulty of properly adjusting the quality of the steam and all the other circumstances, when, as generally happens, the goods are printed with various colors possessing different hygroscopic qualities. When the goods, after being printed, have been left exposed for some time in a moist atmosphere, dry steam is the best; but if wet steam is applied, the operation must be abridged to prevent the running of the colors, and the further precaution must be taken so to adjust the goods and the whole apparatus, that the steam may diffuse itself rapidly and uniformly in all cases. For this purpose the supply of steam cannot be too abundant; because, by reducing in this manner the duration of the operation, the shades are obtained more uniform. On the contrary, if the steam penetrates slowly into the goods, it does not diffuse itself equally; the parts which it first reaches are saturated with moisture, when other parts are scarcely touched at all; and it will be in vain to attempt to remedy this by prolonging the operation, for long before the last parts arrive at the point of saturation, the others, continuing to condense moisture, will be supersaturated with it, and the colors will run.

There are some printers who steam their goods almost immediately after they are printed. This method may succeed in certain cases, and with some colors; but as a general rule it is not to be recommended, since it is difficult, if not impossible, to give by steaming the same degree of fixity to different colors which have not been all printed on the stuff at the same time, and have not therefore the same degree of humidity. It is better, after bringing all the shades to the same state of desiccation, to expose them to conditions in which they will all absorb the necessary quantity of moisture, and thus acquire a perfect uniformity in that respect.

Again, from the important influence which the state of the goods, as regards their dryness or moisture, exerts in the steaming, it is obvious that care must be taken to place or suspend them on the frames, or to roll them on the cylinder, in an atmosphere as similar in temperature and other conditions as possible to that in which they are submitted to the action of the steam. If taken too cold into the steaming-chamber, moisture will condense upon them as soon as the steam is admitted. All variations in the temperature of the atmosphere to which the goods are exposed, should, therefore, be avoided as much as possible.

With regard to the best kind of steaming apparatus to employ, it is difficult to lay down any general rule. It may be stated, however, that in those which are of large dimensions, there is necessarily a greater condensation of water at the beginning of the operation, and, consequently, colors which have not much of a hygroscopic nature, are placed in good conditions for fixing; but to prevent those which are very hygrometric from running, too much care cannot be taken to diffuse the steam rapidly and equally, and with this view to introduce it in sufficient quantity. The smaller forms of the apparatus do not present the same disadvantage; nevertheless, from the rapidity with which the temperature rises in these circumstances, soon rendering impossible any condensation of the steam, the latter must be applied in a moist state. For this purpose, in steaming with the chest, a certain quantity of water is sometimes put into the bottom of the vessel, through which the steam must pass before arriving at the goods.

In January, 1855, a patent was taken by Mr. JOHN GRAHAM, of Hartshead print-works, near Stalybridge, Lancashire, for improvements in fixing certain colors on yarns and textile fabrics, which consist in subjecting them, after being dyed and printed in the usual manner, to the action of high-pressure steam, or a mixture of high-pressure steam and air, or of water heated and under pressure, or mixed with certain chemical solutions which elevate the boiling point of the liquid, so as to expose the yarns or fabrics, for a shorter period than is usually required in steaming, to a temperature ranging from 250° to 300° Fahr., more or less. The colors or lakes to which these improvements are described as having been found most applicable, are garancin, madder, cochineal, logwood, sumach, quercitron, and other dye-stuffs of the same nature, in combination with the oxide of iron, alumina, tin, and other mordants. The special methods enumerated in the specification of this patent are as follow:—1st, The goods may be put into a strong close vessel, in which they are subjected for a period of twenty minutes, more or less, to the action of steam at a pressure of forty pounds on the square inch, or 2nd, Into a vessel containing water, which is then closed, and heated to a temperature of from 250° to 300°, for twenty minutes; or 3rd, Into a vessel which may be open, and in which the goods are submitted, for the same period, to the action of steam alone, or of steam mixed with air at 250° to 300°; or 4th, They may be passed through a strong or nearly saturated solution, capable of being heated to a temperature varying from 220° to 260° Fahr., such as sulphate of soda, chloride of sodium, arseniate of soda, chloride of calcium, or other salts of a similar nature. By thus elevating the temperature either of the vapor or liquid to which the goods are submitted, the duration of the process is abridged, and the fixation of the colors is alleged to be more effectually accomplished.

A few examples may now be given of colors that are printed to be fixed by the steaming process.

Steam-red.—For steam-reds, the coloring matter of cochineal and the decoctions of certain dye-woods, particularly Brazil-wood, are used. In the execution of steam work, the cloth is first run through stannate of soda, then through dilute sulphuric acid. The stannic acid is thus fixed, though it is not a strong base, but when the coloring matter contains alum mordant, the tin gives to all the colors, by its insolubility and its acid character, a richness which cannot be obtained with any other known substance. For Brazil-wood the goods are prepared with a mordant of nitro-acetate of alumina, more or less concentrated; and, as liquors of Brazil, Sapan, and other woods, are usually in a low state of oxidation when they come from the chemical manufacturer, a little chlorate of potassa is added, which supplies the requisite element, and leads to the development of finer and fuller colors than would otherwise be obtained; but the best steam-red for cotton is obtained by decoction of cochineal with oxalic acid and protochloride of tin For this purpose, one gallon of cochineal liquor of 6° Twaddell is boiled with one pound of starch for a few minutes; when this mixture is half cold, three ounces of oxalic acid are added, and as soon as the acid is dissolved, four ounces of crystallized protochloride of tin are introduced. By substituting peachwood for the cochineal liquor, a cheaper, but less brilliant steam-red is obtained.

Steam-yellow.—For steam-yellows, quercitron or fustic, with an aluminous mordant, may be used; but as the coloring principle of Persian berries is much more soluble than that of quercitron, and yields purer shades, it is usually preferred for this purpose. Steam-yellows may be printed on the cloth without subjecting it to any preliminary process; but the shades are brighter and firmer when the goods have been prepared with tin mordants. For a quercitron yellow, to one gallon of the decoction at 7° Twaddell, add one pound of alum dissolved in a quart of water, and thicken with three and a half pounds of gum Senegal. For yellow from decoction of Persian berries, to one gallon of berry liquor at 4° Twaddell, add five ounces of alum thickened with about fourteen ounces of starch. Or, in one gallon of berry liquor at 8° Twaddell, dissolve twenty ounces of alum, and thicken with three ounces of gum Senegal, adding a small proportion of chloride of tin.

Steam-violet.—Steam violets, like the reds and roses, have for their base an aluminous mordant, and the coloring matter is decoction of campeachy, either by itself or mixed with Brazil-wood to modify the bluish tint.

Steam-blue.—The only blues which have yet been fixed by steam are the prussian, either pure or mixed with oxide or cyanide of tin. Indigotin has not yet been applied in this way, its fixation being impossible except by reducing it in presence of a salifiable base, which, by rendering it soluble, enables it to combine with the stuff. For a good steam-blue, dissolve in one gallon of water 6·4 pounds of ferrocyanide of potassium; in another gallon of water dissolve 3·35 pounds of alum, two and a half pounds of oxalic acid, and two and a half pounds of tartaric acid. Mix these liquors, which may be colored with a little nitrate of iron, and thicken with gum. For woollens, bichloride of tin is preferred to the alum; but the latter is used for cotton goods.

For printing on cottons by the cylinder, a very good prussian-blue is obtained by mixing with one gallon of water, one pound and a quarter of yellow prussiate, three to four ounces of alum, five to six ounces of sulphuric acid, thickening with one and a half pounds of starch.

Steam-greens have for their base the ingredients employed for steam-blue, associated with those already given for steam-yellow, varying the proportions according to the shade desired. Though indigo has not yet been applied by the steaming process either for blues or greens, PERSOZ thinks it might be rendered available for that purpose by mixing with it a reducing body, and printing and steaming in presence of ammoniacal gas. Rendered momentarily soluble, it might in these conditions penetrate into the pores of the stuff, to which it would adhere on being oxidized either by exposure to the air or by employing an oxidizing agent.

All the *steam-blacks* are formed by a combination of logwood liquor with nut-gall and iron mordants; but some contain only these principles, while a small proportion of fatty matter, such as Gallipoli oil, is introduced into others.

IV. RESIST STYLE.—The principle of the *resist* or *reserve* style consists in the topical application of some substance which has the effect of protecting those parts of the fabric on which it is applied, from the action of the mordants or tinctorial matters in which the goods are afterwards immersed to produce a colored ground. Such substances are termed resists, reserves, or resist pastes, and ought to admit of being afterwards detached from the stuff by processes which will not injure the colored ground, leaving the parts which they were applied to protect either pure white or any desired shade.

Resists have been used from time immemorial in India and China, where, to produce white designs on colored goods, the practice was to trace the patterns on the white stuff in melted wax, and then to immerse it in the dye-bath, after which the goods were passed into boiling water to melt off the wax. The resists now employed are of different kinds, and may be divided into three classes—mechanical, chemical, and physical. A *mechanical resist* is any kind of preparation resembling in its operation the wax employed by the orientals, and which has the simple effect of protecting the goods from coming into contact with the dye-stuff at those parts where it is applied. A *chemical reserve* is any substance which, when printed on a stuff, without being permanently adherent to it, possesses the property either of precipitating the coloring matter or base of the mordant, and rendering it insoluble, or of altering its properties. By *physical reserves* may be understood insoluble matters, which, in contact with the fabric, absorb the mordant or coloring matter, and prevent it from penetrating the stuff. Such is the effect of pipe-clay when it is deposited upon a fabric, mixed with other substances.

But this classification of the different kinds of resists rather exhibits the different principles on which they act, than any actual division of them observed in practice. It is by the union of these principles in the same resist, just as the different styles of calico-printing are combined to produce a variegated pattern on the same stuff, that the best effect is produced. Pipe-clay, for example, is never used alone, but is mixed with mechanical or chemical resists to increase the efficiency of their action by its absorbent property. These substances may be divided, therefore, into two classes—mechanical and chemical.

1. *Mechanical Resists.*—Those of this class are termed *fat resists*, being, as might naturally be expected, chiefly of an unctuous nature, or substances having for their base resins, fatty bodies, fat or essential oils. Their indispensable property is, that they shall not dissolve in cold water, and that they shall admit of being dissolved off in hot or boiling water. Resists of this nature are chiefly employed for silk and woollen goods, or chalis, and are frequently composed of resin and suet, in the proportion of two and a half pounds of the former to one pound of the latter; or such a resist may be formed by an intimate mixture of suet and gum water. In particular circumstances, however, such resists may be applied to cotton goods. Thus, supposing that red and lilac figures have been printed on a white ground, dyed, and cleared by the madder style, these figures may be covered or overlaid with a resist consisting of suet and gum water, and the whole may then be run over with weak iron liquor for a paler lilac ground, after which the cloth is aged, dunged, re-dyed, and cleared, when the red and lilac of the pattern will be found to have been perfectly protected by the resist.

2. *Chemical Resists.*—These may be subdivided into two classes, according as their influence is exerted on the mordant or on the coloring matter itself.

The active principle of the first class, or of those substances employed to prevent the deposition of a mordant on particular parts of the cloth, is generally an acid or acidulous salt capable of uniting with the base of the mordant to form a compound soluble in water, and not decomposable into an insoluble subsalt during the hanging or ageing of the mordanted goods previous to dunging and dyeing. For the iron and aluminous mordants the resist commonly employed is lemon-juice or lime-juice, or a mixture of one of these with tartaric and oxalic acids and bisulphate of potassa. These juices are preferred to citric acid in the pure form, as the mucilaginous matters which they contain impede the crystallization of the acid within the pores of the cloth, and thus render it better adapted to prevent the attachment of the mordant in an insoluble form. The resist is seldom used of a density higher than 12° Twaddell, but its strength is regulated by that of the mordant afterwards applied. The thickening material is either a mixture of pipe-clay or china-clay with common gum, a mixture of British gum with gum Senegal, or British gum alone.

Instead of the lemon or lime juice, or a mixture of one of these with tartaric and oxalic acids, protochloride of tin—commonly called salts of tin—may be employed as a resist for iron liquor, and will prevent it from affording a deposit of insoluble subsulphate during the ageing. The protochloride of tin, however, is never applied in this way with the view of producing a white figure on a colored ground; it is commonly mixed with red liquor, as the deposition of the insoluble subsulphate of alumina from that preparation is not interfered with by the protochloride.

A solution of citrate of soda, prepared by neutralizing lime-juice of about 4° Twaddell with soda, and thickened with a mixture of gum and pipe-clay, is also much used as a resist for red and iron liquor. The principal use of neutralized lime-juice as a resist for iron liquor, is to protect figures previously applied in madder colors; for which purpose the free acid is quite inapplicable, as it would dissolve the mordant on the cloth in combination with the tinctorial matter.

The second class of chemical resists comprises those which are employed to produce a white or tinted pattern on a colored ground, by acting directly on the coloring matter itself. Such resists are chiefly employed in connection with the indigo vat, and the substances commonly used for this purpose, that is to say, to resist or modify the deposition of the indigo on certain parts of the stuff, are the sulphate and the acetate of copper, and the sulphate of zinc. Other salts of copper, and likewise the chloride of zinc and chloride of mercury, as also a mixture of the latter and biarseniate of potassa, are employed for the same purpose; but the three first-mentioned salts are those most generally applied.

A simple *white resist*, which means a resist for producing a white pattern, when the goods are to be dipped in the blue vat, may be composed as follows:—Dissolve in a gallon of water, one pound of acetate of copper, and three pounds of sulphate of copper; thicken with two pounds of gum Senegal, one pound of British gum, and four pounds of pipe-clay, adding afterwards, as a deliquescent ingredient, two ounces of nitrate of copper. When such a resist has been printed on those parts of the cloth which are not intended to absorb the indigo, the goods are suspended for one or two days, according to the composition of the resist, in a chamber which should be rather humid than too dry, and at a common temperature. The pieces are then fixed on a frame and dipped into the indigo vat, which contains in solution the colorless hydride of indigo or indigotin. The solution of indigotin is immediately absorbed by the cloth on all parts where the resist had not been printed, and these parts become deep blue when the cloth is afterwards exposed to the air, the soluble indigotin passing into the state of insoluble indigo-blue by absorbing oxygen. But wherever the resist had been applied, the solution of indigotin is not absorbed by the cloth, partly on account of the action of the pipe-clay, or the resistance of any unctuous matters which may have been added to the resist, but chiefly from the action of the metallic salt on the indigotin in solution, by which either indigotin, or else indigo-blue, becomes precipitated before the solution reaches the interior of the fibre, and when once thrown down, it is rendered incapable of being absorbed by the cloth. The indigo-blue formed by the resist, being merely attached to the surface of the stuff, is easily removed by washing.

The sulphate of zinc, when used as a resist, acts in a different manner from the sulphate or acetate of copper or the chloride of mercury. When stuffs printed with resists containing the latter are introduced into the indigo vat, the first chemical change which occurs is the decomposition of the metallic salt in the resist by the alkali or lime in the vat, whereby the cupreous salts afford a precipitate of hydrated oxide of copper, and the chloride of mercury—corrosive sublimate—a precipitate of oxide of that metal. These oxides are no sooner produced than they exert an oxidizing action on the indigotin in solution, and become reduced to the state of inferior oxides. The sulphate of zinc, on the contrary, exerts no oxidizing action on the indigotin, but causes the precipitation of that substance in an insoluble state, by withdrawing the lime which holds it in solution. This salt is used only in cases where it would not be allowable to expose the goods to dilute sulphuric acid, after having been dipped into the blue vat, as if, for instance, a design had been applied in madder colors, this operation being unnecessary with the zinc salt.

The receipt for a white resist given above is intended for a full body of blue. But the composition of the resist paste must be varied according to the depth of color in the blue ground. Thus, to compose a white reserve for light blues, dissolve in one gallon of water one pound of sulphate of copper, and four ounces of acetate of copper; and thicken, as before, with two pounds of gum Senegal, one pound of British gum, and four pounds of pipe-clay.

For protecting a design in madder colors, as well as for preserving some white, a sulphate of zinc resist may be composed as follows: Dissolve four to five pounds of the sulphate in two quarts of boiling water; with this solution, while warm, mix five and a half pounds of pipe-clay, four ounces of soft soap, and two ounces of hogs' lard, thoroughly incorporating the whole together; and, when the mixture is cold, add two quarts of gum Senegal water, containing three pounds of the gum.

A great variety of colored designs on a blue ground may be obtained by combining with the resist, either one of the saline solutions capable of imparting a mineral color, or else the mordant for a coloring matter to be applied by the madder style. As an illustration of the former, a chrome yellow design on an indigo ground may be obtained thus:—In one gallon of water dissolve three pounds of nitrate of lead, and one pound of acetate of copper; to this solution add half a pound of subacetate of lead; thicken with three pounds of gum and six pounds of pipe-clay; grind all the ingredients together, and pass through a sieve. The cloth is printed with this paste on the parts which are intended to be chrome yellow; the goods are suspended for a day or two as usual, and then dyed in the indigo vat. They are afterwards rinsed for half an hour in a solution containing five ounces of bichromate of potassa per piece of calico, and also in a bath of dilute hydrochloric acid, till the chrome yellow becomes sufficiently bright.

The second method for producing a colored figure on the indigo ground—that of combining with the resist a mordant for a vegetal coloring matter to be applied by the madder style, after the cloth has been dipped into the indigo vat—is susceptible of a great variety of modifications, and is distinguished as the *lapis* or *lazulite style*, from the resemblance of the calico thus printed and dyed to the mineral *lapis lazuli*. It is known also as the *neutral style*. As an illustration of this process, the method of producing a red figure on an indigo ground may be given:—First, to prepare the resist, six pounds of alum are dissolved in two gallons of boiling water; to this solution are added four pounds of crude acetate of lead, then four ounces of chalk, in small quantities at a time; and, lastly, six ounces of sulphate of zinc. When these materials have been thoroughly incorporated, the mixture is allowed to settle, and the clear liquor is decanted off. Then, assuming, as a standard for proportioning the other ingredients, that one gallon of the clear liquor is used, add to it three ounces of acetate of copper, eighteen ounces of gum Senegal, five pounds of pipe-clay, four ounces of soft soap, and, for sightening, a little ground indigo. After being printed with this resist, the cloth is aged for two or three days, and then subjected to the following operations :—1. Drawing by rollers *once* through the blue vat; 2. rinsing in water; 3. dunging or branning; 4. washing at the dash-wheel; 5. dyeing in the madder-beck, with from two to five pounds of madder per piece; 6. clearing, by boiling first in bran water, and afterwards in soap water.

Variously colored patterns on a blue ground are produced in a similar manner by this combination of resists with the madder style and the indigo vat.

V. DISCHARGE STYLE.—This style has many points of resemblance to the last; but there is this important difference between them, that while it is the object of the resist style to anticipate and prevent the deposition of certain colors on particular parts of the stuff, the object of the discharge style is to produce a white or colored pattern by the elimination, at determinate parts of the stuff, of a color or mordant already deposited upon it. This is accomplished by the topical application of what is termed the *discharger* to a cloth already mordanted or dyed, and is applicable to both mineral and vegetal coloring matters.

The words *white discharge*, for example, indicate an action by which a substance, printed on a stuff covered with a mordant or a color, causes the one or the other to disappear, so as to produce the design of a white figure. The essential quality of a white discharge belongs, therefore, to any substance which, either by a pure and simple combination with the matter fixed on the stuff, or by alterations which it produces upon it, brings it to such a state that not only does it cease to adhere to the cloth, but may be so completely and thoroughly washed off as to leave the white parts quite in their original state, and fitted for the reception of other colors either by dyeing or printing.

The matters capable of fulfilling such functions in all the cases that arise are not, and cannot be, of the same nature; for four general cases present themselves, each of them requiring, more or less, different properties in the discharger. According to the mordant or color employed, this discharger may be required to act on either of the following substances:—1. On a mordant or metallic oxides; 2. On organic coloring matters which have been fixed on the stuff without a mordant; 3. On organic coloring matters united to a mordant; 4. On inorganic colored compounds.

For the sake of simplicity, however, it may be sufficient to consider the subject under three heads: First, dischargers for organic coloring matters; second, dischargers for mordants; and, third, dischargers for inorganic or mineral coloring matters.

1. *Dischargers for Organic Coloring Matters.*—The two substances chiefly employed for this purpose are chlorine and chromic acid. In the article on BLEACHING, the decoloring action of chlorine on vegetal matters has been fully explained, and it is in virtue of that action that it is applied by the printer to remove vegetal colors from certain parts of the cloth. For indigo, chromic acid is chiefly employed; but for madder or other vegetal dye-stuffs fixed by a mordant, chlorine is applied to discharge or destroy the coloring principle.

A solution of the chloroxide of calcium or bleaching powder is generally employed for this purpose; but, as was explained in the article on Bleaching, this substance does not produce its effect, or acts only very slowly, except in presence of an acid to disengage the chlorine. Advantage is ingeniously taken of this circumstance by the printer, who, to produce the topical discharge of a vegetal coloring matter with which the goods have been previously dyed over the whole surface, does not apply the chlorine directly, but prints on those parts which are to be discharged a thickened acid mixture, and then passes the goods through a solution of the bleaching liquor. In this operation, the whole surface of the goods is exposed to the solution; but if the immersion is continued only for a short time, the action of the chlorine is limited to those parts which have been previously printed with the acid mixture.

It is but justice to state that this ingenious process, which deserves to rank as one of the most important discoveries in calico-printing, was invented by M. D. KŒCHLIN in 1811, and was the result of a series of elaborate researches expressly undertaken with the view of applying an effective topical discharge to Turkey-reds. It was only after attempting in vain, by a multiplicity of methods, to use the chlorine or the oxychloride of calcium *directly* as a discharger, that the happy idea occurred to this distinguished scientific printer, of first applying an acid substance, and then exposing the goods to the action of the chloride solution.

It is quite unnecessary to enter into any detail of the chemical reactions which take place in this process. These are perfectly simple, and have been already discussed in connection with the application of chlorine to bleaching in general. It will be sufficient to state that the acid applied to certain parts of the cloth combines with the base of the oxychloride, and liberates free chlorine, which exerts an instantaneous bleaching action on the vegetal coloring matter on those parts of the cloth, while the other parts remain comparatively unaffected. It is true, however, that the more delicate colors are readily discharged by the oxychloride solution alone, and, therefore, this process can only be applied for the topical discharge of fast colors, such as Turkey-red and other madder colors, and indigo.

For all madder colors except Turkey-red, a white discharger may be made by dissolving four pounds of tartaric acid in a gallon of water, mixing the solution with a gallon of lime-juice of 44° or 48° Twaddell, and thickening the mixture with pipe-clay and gum. The Turkey-red discharger requires to be somewhat stronger. It may be made by mixing four pounds of tartaric acid with a gallon of lime-juice at about 30° Twaddell, and after thickening with pipe-clay and gum, adding about a pound of concentrated sulphuric acid, or two pounds of bisulphate of potassa.

PERSOZ recommends the following as a white discharge for Turkey-red. In one gallon of water dissolve twelve pounds of tartaric acid; to this solution add eight pounds of pipe-clay, one pint of gum-water containing ten pounds of gum to the gallon, and lastly 1·7 pounds chloride of tin at 168° Twaddell. For another discharger given by the same writer, the tartaric acid is reduced to eight and a half pounds, and for a third to five pounds, the other ingredients remaining nearly the same, except that in the third the chloride of tin is omitted, and the proportion of gum water increased.

The tartaric acid in these discharges does not merely combine with the base of the oxychloride, it performs another important function by dissolving the base or mordant of the color—the iron or aluminous oxides with which the goods had been prepared to receive the color. But this is a point which will fall to be explained in treating of the dischargers for mordants.

When the goods have been printed with one or other of these dischargers, according to the fastness of the color to be destroyed, they are sometimes suspended to dry for a day or two before being passed into the oxychloride solution. But, as the tartaric acid has the property of attracting moisture even from a very dry atmosphere, the goods ought to be passed into the solution immediately after being printed with the discharger. The solution, which should not be stronger than 8° Twaddell, is usually contained in a rectangular cistern of wood, lined with lead; six or eight feet long, three feet wide, and four or five feet deep. The calico is drawn through this bath by a pair of squeezing rollers, and should not occupy more than two or three minutes in its passage. It is then put to soak in water; after which it is washed either at the dash-wheel or in the rinsing machine, and is then dried.

The only method by which chlorine, or rather an aqueous solution of chlorine, has hitherto been applied directly to the goods as a topical discharge, with any success, is by firmly compressing the cloth at those parts which it is desired to protect from the action of the decoloring agent, and leaving it uncompressed at those parts where it is intended that this agent shall penetrate. PERSOZ remarks that the idea of a process exactly the reverse of this, but the same in principle, namely, of obtaining designs or patterns by compressing the corresponding parts of a white or colored fabric before passing it into a dye-bath, is very ancient, and appears to have been first realized in India. A machine invented in Scotland has been constructed on this principle, with which, by the action of chlorine or other chemical agents exerted only on the uncompressed parts of the fabric, white or colored patterns, on colored grounds, may be produced at pleasure. This is known by the name of *Bandana printing*; being chiefly applied to the printing of white designs for handkerchiefs on Turkey-red grounds. It is in this way, indeed, that the celebrated bandana handkerchiefs have been most successfully imitated by Messrs. MONTEITH of Glasgow.

Before proceeding to explain minutely the different parts of this machine, which is one of the most ingenious contrivances connected with the art of calico-printing, a general account of its mode of action may be given, as follows:—From ten to fourteen pieces of cloth, previously dyed Turkey-red, are stretched or folded over each other quite flat and parallel, and passed together by portions at a time between two leaden plates, one of which is superimposed immediately over the other. In this way the operation advances from one end of the pieces to the other. Each of the parallel leaden plates is cut or pierced completely through, in parts exactly opposite to each other, so as to leave hollow places on all the parts required in white on the red ground. By means of a hydraulic press, the pieces of cloth are compressed between the leaden plates with a force of three hundred and twenty tons on the whole surface. While the cloth is exposed to this immense pressure, an aqueous solution of chlorine, obtained by adding sulphuric acid to a solution of bleaching powder, is made to percolate downwards through the pieces by the openings in the leaden plates. As the compressed state of the cloth prevents the imbibition of the liquid, except by the parts opposed to the design on the lead, the solution passes on in a circumscribed channel to the lower leaden plate, where it escapes, and is conveyed away by a waste-pipe. The portions of cloth through which the liquid passes are thus entirely deprived of their color. Water is then made to percolate in a similar manner to wash away the chlorine. The passage of the chlorine solution and the water through the cloth, is sometimes assisted by a pneumatic apparatus consisting of a large gas-holder, from which a current of air is forced under a moderate pressure, so as to act in the direction of the percolating liquid. It is evident that tinged liquids may be passed through in the same manner; or, after the production of a white figure on a colored ground by the action of the chlorine solution, colored figures may be applied either to the ground or to the white figure, by grounding in topical colors by the hand-block. A common method of imparting a tinted figure, is by mixing with the acid discharger one of the two solutions necessary for producing a mineral coloring matter.

If to the essential parts of the apparatus to which allusion has been made, be added cylinders for giving motion to the pieces, becks for washing them on coming out from the presses, *et cetera*, a general idea may be formed of the machine, of which the details will now be explained.

In the first place, however, it may be stated that, to render the operation continuous, a certain number of hydraulic presses are required. In the establishment of Messrs. MONTEITH, Glasgow, from which the annexed designs—Figs. 406, 407, and 408—are taken, sixteen presses are connected together in fours; and each system of four presses, with room enough between them to allow the workmen to move freely, occupies about eight yards of surface; consequently, the whole sixteen extend about forty yards in length.

A represents the capital; B, B, B, the pillars; F, the base of one of these presses; C, the upper platin, to which is fitted one of the lead plates engraved or cut through. This plate is adjusted so as to be perfectly parallel to the lower one, by means of a universal joint, and kept in its position by screws, N N. D is the lower platin or table, supporting the other engraved plate. These platins or press-plates are fitted into a strong case or frame of iron, the raised edges of which form a kind of trough or box a little larger than the leaden plate which it is intended to receive. As it is important that when the blocks approach each other to compress the folded goods between the two plates, the latter should not deviate from their position in the smallest degree, openings are made at the four corners of the frames, which fit into iron projections on the pillars, preserving their parallelism so perfectly that, if they were brought into actual contact, they would form, as it were, only one plate. E is the cylinder which, by pressing with its ram against the block, D, forces it to rise and to compress the goods placed between it and the upper block, C. G, a beck into which the goods fall after coming out of the press; *a*, *a*, tubes to allow the escape of the air from the goods and the interior of the press, when it is put into operation, and the liquid arrives at the upper surface of the plate, *m*. *b*, a tube for conducting the compressed air, which, by pressing on the mass of the bleaching or coloring liquid, forces it to pass through all the folds of the goods. C, stop-cock, by means of which either a decoloring solution, or a colored liquid, or pure water, is admitted at pleasure from the reservoir, H. *d*, *d*, graduated glass tubes which indicate the quantity of liquid contained in the reservoir, H, and consequently enable the operator to observe how much has been employed for each operation. *e*, *e*, glass stop-cocks for introducing the bleaching liquor into the reservoir, H. *g*, *g*, engraved plates fixed to the blocks, D, C.

Fig. 404.

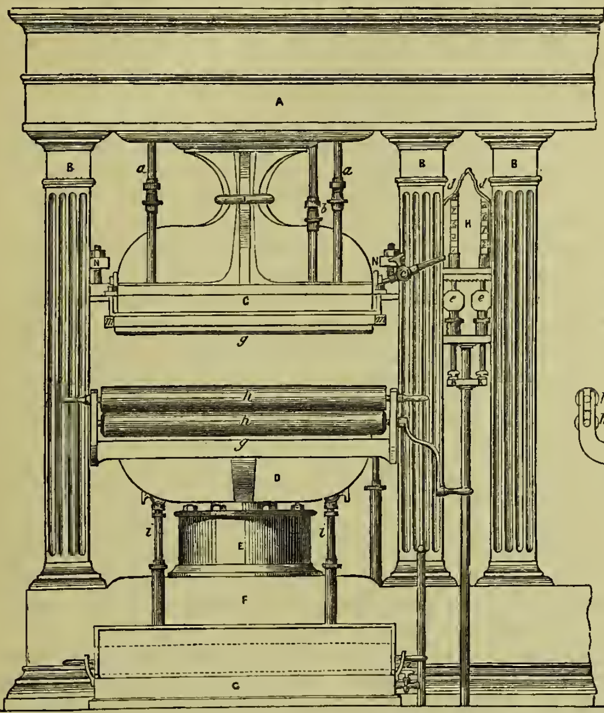


Fig. 405.

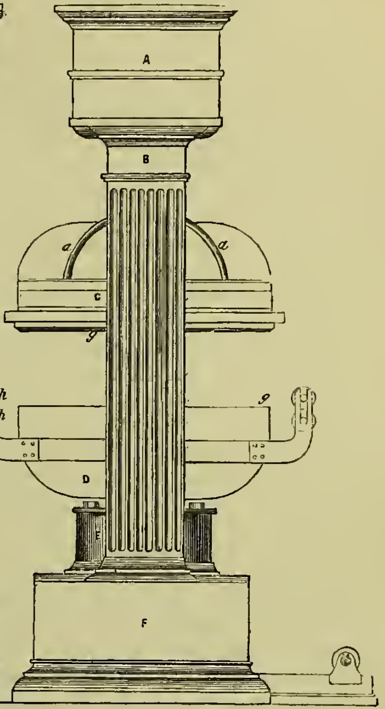
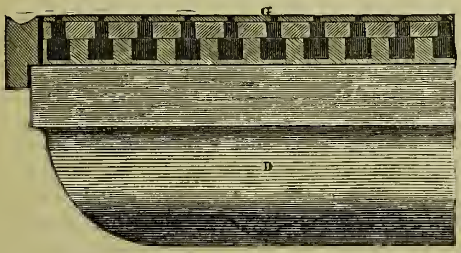
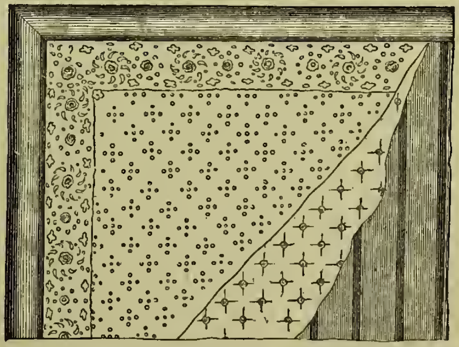


Fig. 406.



To prevent these engraved plates, which are very thin, from yielding to the pressure and being put out of shape, they are soldered by the edges to a leaden plate nearly half an inch in thickness, and pierced with a multitude of small holes to allow the air and the liquid to pass freely through the openings which do the work of the engraving. To the edges of this plate of lead is soldered a sheet or rim of the same metal, which, rising over the edges of the frame, keeps in the liquid intended to pass through the goods. One of the engraved leaden plates, so adjusted, is represented in the annexed engraving—Fig. 407.

Fig. 407.



The preparation and engraving of the plates are very simple. After being hammered out, they are smoothed with the plane, and a paper containing the design to be engraved is glued or pasted upon them.

The outlines of the figure are then sketched on the metal with a tracing point, and the operator has only to work out with the graving tool or chisel all the parts that are to be removed or left void. Then, as the second plate must correspond to the first with mathematical precision, the latter is covered with printing ink and applied to the other, when the two are submitted to the action of a press. A perfect pattern of the first plate is thus reproduced upon the other, and this has only to be carefully cut out.

m, *m*, projecting edges, pierced with holes three or four inches in depth, to which correspond iron pins placed on the lower frame, to maintain the most perfect parallelism between the plates while they are approaching each other. *h*, *h*, cylinders for passing out the pieces from the presses into the becks, which are filled with water by the stop-cock, *z*. *i*, *i*, tubes by which the liquors and water flow after passing through the goods.

When the printing is about to be proceeded with, the pieces, about fourteen in number, as already stated, are unrolled from a wooden cylinder by a workman, who, with the assistance of hooks fixed at the four corners of the press-table, folds the goods very regularly on the lower plate. This operation being finished, a first movement given to the presses suddenly raises the block, D, towards C; a second movement gives the goods the pressure required, and then, by a turn of the stop-cock, the liquids to be passed down through them are let out from the cistern, H. The power is applied by hydraulic presses, which may be stationed outside the printing room. The stop-cocks, *a*, *a*, are first opened to allow the air to escape; then the stop-cock, C, through which the liquid flows and penetrates the impressed parts of the stuff, passing through the openings in the block, and on the upper plate, C. When these parts are filled with the fluid, the stop-cocks, *a*, *a*, and C, are closed, and the stop-cocks, *b*, *b*, opened, to give access to the column of compressed air, which forces the liquid through the goods in the direction cleared for it in the openings of the engraved lead plates, *g*, *g*, and finally through the tubes, *i*, *i*, into a cistern placed at the foot of the machine.

By exactly the same process, several liquors may be passed through the goods in succession, either to bleach, or color, or wash them; but as it often happens that the column of compressed air does not exercise sufficient force to cause the liquid to pass through as quickly as may be desired, the force of the air is increased by applying additional pressure to the air cistern. As soon as the liquid has produced its effect, and the goods have been washed with the water passed through them by the same means, the washing is completed by immediately emptying them into the water beck placed at the foot of the apparatus.

It has been stated, that the only substance besides chlorine which is commonly employed as a discharge for vegetal coloring matters is chromic acid, and that this substance is generally applied in connection with the indigo vat. Like chlorine, however, the chromic acid cannot be conveniently or safely applied directly to the cloth, and therefore was comparatively useless for this purpose till the following method of using it with safety and success was discovered by Mr. JOHN MERCER of the Oakenshaw Print Works, near Accrington, about the year 1826. This discovery is usually ascribed to the late Mr. THOMPSON of Clitheroe, but the Editor has evidence in his possession that the process was first practised by Mr. MERCER.

The cloth being dyed with indigo in the usual manner is padded with a solution of bichromate of potassa, containing about eight ounces of the salt to the gallon of water. This operation, as well as the subsequent drying of the goods, must be performed in a dim light, for the instant effect of a strong light would be to destroy the beauty of the blue color, and even to injure the cloth itself. The goods are sometimes dried in the shade at the ordinary temperature; but PERSOZ recommends an immediate and rapid desiccation in the hot stove. The cloth is then printed with a discharger containing tartaric acid, oxalic acid, citric acid, and sometimes hydrochloric acid. PERSOZ, however, suggests for roller-printing the following, containing only oxalic and sulphuric acids:—In two-thirds of a gallon of boiling water, dissolve two pounds of oxalic acid; to the remaining third, add seven and a half pounds of roasted starch, twelve and a half pounds of sulphate of lead, and 1·28 pounds of sulphuric acid; then mix the whole. When the cloth has been printed with this discharger, it is immediately winced in water containing some chalk in suspension; then rinsed at the dash-wheel, passed through dilute sulphuric acid, and, lastly, washed in clean water.

The discharger is no sooner applied to the cloth in this process, than the color of the indigo is destroyed, chromic acid being then liberated from the bichromate through the superior affinity of the acids in the discharge paste for the potassa, and the free chromic acid at once oxidizes and destroys the coloring matter. To produce a yellow instead of a white figure by this process, the acid discharger, says PARNELL, may be mixed with a salt of lead; but sulphate of lead forms a very large constituent in PERSOZ' recipe, above quoted, for a white discharge.

2. *Dischargers for Mordants.*—Instead of waiting till the goods have been mordanted and dyed, and then applying a discharger which shall combine elements both for destroying the color and dissolving off the mordant, it seems to be a shorter and more direct method to apply the discharger on the mordant, and then to dye the goods, in which case the coloring matter will only adhere to those parts on which the discharger has not been applied. The name of the *discharge* or *rongeant* style is exclusively applied by some writers to this process of removing the mordant previous to the application of the coloring matter, while the method of applying chlorine or other substances to act directly upon the tinctorial matter itself, is termed the *enlevage* or *decoloring* style. Both, however, are equally discharging processes, and when it is considered that compound mineral colors are really composed of ingredients which act as mordants to each other, there seems to be no substantial foundation for this distinction of styles.

The substances employed for dischargers of mordants must be such as shall be capable of combining with the metallic oxides which constitute the bases of these mordants, while, at the same time, the combination so formed shall not itself act as a mordant. Three organic acids—the tartaric, the citric, and the oxalic—are chiefly employed for this purpose. Some inorganic acids, such as the sulphuric, the nitric, and the hydrochloric, would act with greater energy, but would destroy or injure the fabric. It is chiefly to produce white or colored figures on grounds of madder and logwood, that the three organic acids above mentioned are applied to discharge the iron or aluminous mordants before dyeing the goods. Instead of the pure citric acid, however, lime or lemon juice is always preferred, for the reason already stated. To discharge the mordant from a piece of cloth impregnated with red liquor of specific gravity 7° Twaddell or weaker, or with iron liquor at 2° Twaddell or weaker, the following mixture may be used—namely, one gallon of lime-juice of specific gravity 6° Twaddell, three and a half ounces of oxalic acid, and four ounces of tartaric acid. If this mixture is to be applied by the block, it may be thickened with pipe-clay and gum, or with British gum if by the roller. It may be remarked, that whenever the two last mentioned acids are used, they should always be accompanied by treacle.

To procure a white design on a black ground by the discharge of the mordant, the cloth may be treated in the following manner:—1. Pad or print the calico with a mixture of equal measures of iron liquor of 6° Twaddell, and red liquor of 8° Twaddell, thickened with starch or British gum; 2. Dry over the steam-boxes, age, and apply a discharger composed of tartaric acid, sulphuric acid, and lime-juice, thickened with British gum; 3. Pass the cloth through warm water mixed with chalk; 4. Dye in decoction of logwood mixed with a little bran and dung; 5. Wash, clear the white by branning, rinse, and dry.

The action of these organic acids in discharging mordants, will explain their application in connection with chlorine and chromic acid, for discharging coloring matters which have been fixed by mordants.

3. *Dischargers for Mineral Colors.*—Mineral colors are discharged on precisely the same principle as the mordants, and here also the same organic acids are largely employed. Thus, to obtain a white figure on a ground of iron buff, a mixture of tartaric and oxalic acids with lime-juice thickened with pipe-clay, or China clay and gum, is applied to the cloth. The base of the buff color is sesquioxide of iron, which is dissolved by the acids, and the figure is obtained perfectly white by washing. This case, indeed, may afford a good illustration of the analogy between the discharging of mineral colors and of mordants properly so called, for the readiest way of discharging the iron is to apply the acid mixture after the cloth has been padded in the buff liquor, and before it is exposed to the soda solution to precipitate the sesquioxide of iron.

Again, to produce a white figure on a ground of prussian blue, the cloth is printed with a paste containing a caustic alkali, and afterwards passed through a solution of oxalic acid. In this case, the prussian blue is first decomposed by the alkali, affording either yellow prussiate of potassa or prussiate of soda, while sesquioxide of iron is precipitated on the cloth. The latter is dissolved out by the oxalic acid, while the alkaline salt is removed by washing.

A beautiful chrome yellow discharge is obtained by dissolving litharge—oxide of lead—in tartrate of potassa and soda, with excess of the latter, thickened with gum tragacanth. After printing, expose to the atmosphere; the lead soon becomes carbonated; wash off and dye in bichrome with a little nitric acid.

Any substance may be employed, however, which will have the effect of decomposing the mineral color, and of forming with its constituents new combinations which shall be either colorless, or capable of being washed off. The proper discharger for a mineral color of which the composition is known, is, therefore, a purely chemical problem in the strictest sense of the words. Thus, a white figure may be produced on a ground of manganese brown or bronze, by simply printing on the cloth a slightly acid solution of protochloride of tin, containing one and a half, or two pounds, of the protochloride per gallon, and thickened with about a pound of starch to the gallon. The brown coloring matter is known to consist of binoxide of manganese, which is decomposed by the protochloride of tin, and converted into the soluble protochloride of manganese, while binoxide of tin is precipitated on the cloth. Thus the conditions of the two compounds are exactly reversed. The binoxide of manganese is converted into the protochloride, and the protochloride of tin is converted into the binoxide, as shown in the annexed equation:—

$$\underbrace{Mn\,O_2}_{\text{Binoxide of manganese.}} + \underbrace{Sn\,Cl}_{\text{Chloride of tin.}} = \underbrace{Sn\,O_2}_{\text{Binoxide of tin.}} + \underbrace{Mn\,Cl}_{\text{Chloride of manganese.}}$$

The new manganese compound is easily dissolved off by washing, and the oxide of tin being white, although it adheres to the cloth, produces the kind of figure desired.

Generally, in such cases, the printer has in view the production of a white figure, with a view to the subsequent deposition of another color upon it different from that of the ground. In such cases the binoxide of tin, already formed on the pattern, acts as a mordant for certain vegetal dyestuffs, such as logwood or quercitron, the coloring principles of which may be applied afterwards. Or these may be printed on the cloth along with the tin, and their corresponding mordants. Thus, to impart a design in white, blue, and yellow on the same bronze ground, the cloth on which the manganese has been raised may be printed with the salts of tin for the white; with a mixture of berry liquor, alum, and salts of tin for the yellow; and with a mixture of salts of tin, prussiate of potassa, nitrate of sesquioxide of iron, hydrochloric acid, and British gum for the blue, using, of course, as many different blocks or rollers. It may be added, that protochloride of tin, when mixed with sulphuric and tartaric, or oxalic acid, is also used as a discharger for chrome-yellow and chrome-orange.

VI. CHINA BLUE STYLE.—Prior to Mr. MERCER'S discovery of the method of applying chromic acid as a discharger, the only means generally employed for producing a white or light-colored figure on indigo blue grounds, was either by the topical application of resist pastes, or by that peculiar process termed the *China blue style.* This is an interesting modification of the topical style, practised only with indigo, and by which a pattern is formed, consisting partly of white, and partly of different shades of blue. Its peculiarity consists in this, that whereas in the common process of dyeing with the indigo vat, the insoluble indigo-blue is hydrogenized or deoxidized, and converted into soluble indigotin in the vat, this process, in the China-blue style, is effected upon the cloth itself. The insoluble indigo is first printed upon the cloth, mixed with certain ingredients, and then it is reduced to the soluble state and washed into the pores of the stuff by a series of alternate immersions in alkaline and iron solutions. What is remarkable about this process is the fact, that the different shades of blue should thus be dissolved upon the fabric, so as completely to penetrate its texture, without intermixing with each other, staining the parts left white, and blending, in short, into one uniform blue ground.

This is by no means a new process; on the contrary, it seems to have been discovered and practised at a very early period in the history of calico-printing, and long before any correct idea could be formed of the chemical reactions which take place. Persoz states that he has in his possession specimens of this kind of printing, which must have been executed nearly a century ago; but he shows that prior to 1780, if not down to a later period, goods were never printed in this manner with more than one shade of blue. The same writer justly remarks, that he must have been either a bold man, or a person possessed of knowledge in advance of his age, who, to combine indigo with the stuff, did not hesitate to render soluble upon that stuff, in presence of a liquid, the substance which he had deposited upon it in an insoluble state; for, without having tested the fact by experience, it was natural to expect that the liquid would thoroughly dilute the color as soon as it became soluble, and render impossible the realization of any design whatever.

The details of the process adopted in this style of printing are as follow:—The indigo is first coarsely ground, and then mixed with other ingredients in the proportions subjoined:—

16 pounds of indigo,
4 pounds of orpiment—sulphide of arsenic,
22 pounds of copperas—sulphate of iron, and
10 gallons of water, or water and gum-water.

The whole of the water is not added at once. The indigo, sulphide of arsenic, and sulphate of iron, are ground together in a mill for three days with five gallons of water. The mass is then removed, and the mill is washed with a gallon of water, which is added to the mixture; the remaining four gallons of water, or, if a very thick blue is required, as many gallons of strong gum-water, are afterwards introduced. The different shades of blue are produced by diluting this mixture with different proportions of water or gum-water. It is evident that the mere addition of gum, when the same quota of water is used, does not alter the depth of the shade, but merely the thickness or consistency of the color. Assuming, therefore, as the unit or standard the mixture formed with the quantity of water or gum-water above-mentioned, and calling this No. 1 in the following table, the other numbers will serve as a reference for lighter shades, procured by diluting the standard mixture with certain measures of water or mucilage in the proportions stated:—

Course of Shades.	Quantity by measure of No. 1.	Quantity by measure of water or mucilage.
No. 1	1	0
" 2	11	1
" 3	10	2
" 4	8	4
" 5	6	6
" 6	4	8
" 7	2	10
" 8	2	12
" 9	2	14
" 10	2	16
" 11	2	18
" 12	2	20

In this table, constructed by M. Thillaye, the printer is furnished with the requisite proportions of water or gum-water, for twelve different gradations of blue, proceeding from the original mixture, No. 1, which is almost black, to a shade in which that mixture is diluted with ten measures of water.

For a pattern in China blue, to consist of one, two, three, or any number of these shades, associated with white, the proper shades are selected, and the color, suitably diluted and thickened, is printed on the stuff with a separate block or cylinder for each shade. Thus, for the impression of a single blue, with small dots, No. 5, thickened with starch, may be printed by the block, or No. 4, thickened with gum, by the cylinder; for an impression of two different blues with the block, No. 4 with starch, and No. 9 with gum; for an impression of three blues with the block, a good combination is formed by No. 5 with starch, No. 7 with starch, and No. 10 with gum.

After being printed, the calico is suspended in a moderately dry and airy apartment for a day or two, and is then dipped in a certain order into three vats, which may be distinguished as the lime, the iron, and the soda vats, and are composed as follows:—

Lime Vat containing 100 pounds of lime to 600 gallons of water.
Iron Vat „ solution of sulphate of iron of specific gravity 1·048.
Soda Vat „ solution of caustic soda of specific gravity 1·055, made from soda crystals, quicklime, and water as usual.

For immersion in these vats, the goods are stretched in perpendicular folds on a rectangular wooden frame, suspended by pulleys from the ceiling of the apartment. The vats consist of three adjacent stone cisterns, the tops of which are on a level with the ground, and their usual dimensions are eight or nine feet in length, four in depth, and three in width. The frame with the cloth is then dipped into these vats or cisterns in the following order, *continuing each immersion for ten minutes, and draining for five minutes after each dipping.* 1. In the lime vat; 2. In the iron vat; 3. In the lime vat; 4. In the iron vat; 5. In the soda vat; 6. In the iron vat; 7. In the lime vat; 8. In the iron vat; 9. In the lime vat; 10. In the iron vat; 11. In the soda vat.

Allowing to each of these immersions and subsequent drainings the time above stated, the whole operation, assuming no time to be lost, will occupy about three hours. When submerged in the lime vat, a gentle swinging motion is communicated to the frames; and, after the last dip and draining are given, the calico is plunged, upon its frame, into a fourth similar vat, containing sulphuric acid, of about the specific gravity 1·025, or 5° Twaddell. This is for the purpose of removing the oxide of iron deposited upon the calico in the alternate passages through the sulphate of iron and lime vats. The goods are then rinsed in running water, and finally brightened by a second immersion in the above diluted sulphuric acid, slightly tepid. Sometimes the clearing of the white ground is completed by exposing the cloth to a soap liquor at the temperature of 120°.

Having thus stated the details of the different ingredients and operations required, it may be observed that the theory of the process admits of satisfactory explanation by the light of modern chemistry. The cloth, in the first place, is simply printed with a pigment consisting of insoluble indigo-blue, mixed with sulphide of arsenic and sulphate of copper. When this is dipped into the first vat containing lime, a film of the sulphate of iron is decomposed, its sulphuric acid combines with the lime, and protoxide of iron is liberated, which deoxidises a film of indigo, thereby rendering it soluble in lime-water. In this state it penetrates the fibre, and on exposure to air during the subsequent draining absorbs oxygen, so as to become insoluble and fixed within the pores of the stuff. On dipping the calico into the second vat, containing sulphate of iron, a layer of oxide is formed on its surface by the action of the lime-water which remains on the stuff, and this oxide deoxidises another film of indigo, which is dissolved by a second immersion in the lime vat. Thus, the successive films of indigo are deoxidised, dissolved into the stuff, and re-oxidised; producing a progressively increasing fixation of indigo within the fibres. The frame is shaken in the lime vat to detach the deposit of sulphate of lime which falls upon the cloth, but it is kept motionless in the copperas bath, to favor the deposition of as much protoxide upon it as possible.

It will be observed that in this theory of the process, which is, upon the whole, satisfactory in a general way, the presence of the orpiment or sulphide of arsenic has not been recognised at all. PARNELL remarks that it seems to act chiefly by increasing the density of the mixture, thus preventing its ready disintegration and removal by the various liquids to which the cloth is exposed; and that it also assists, probably, in deoxidising the indigo-blue in conjunction with the lime. PERSOZ, however, in different receipts which he gives for China blues, omits the orpiment entirely, and, as it appears to be difficult to see how it can really exert a beneficial action, perhaps it might be wholly dispensed with. Thus, for a blue to be printed by the roller, PERSOZ gives the following ingredients:—

17·5 pounds indigo,
17·5 pounds sulphate of iron,
5·5 gallons of water; thickened with
33 pounds gum arabic.

Another receipt which he gives for printing with the block is as follows:—To a gallon of water add one quart of honey, eleven ounces of pulverized indigo, eleven ounces of sulphate of iron, and thicken with one pound of starch.

The mixture which was mentioned first of all, and to which M. THILLAYE'S table of twelve gradations is adjusted, differs considerably from that which is commonly employed in this country. English printers, instead of the sulphate, generally use the acetate of iron —iron liquor—and British gum, in lieu of common gum. Employing these ingredients, the following proportions are given by PARNELL as forming a suitable mixture:—

16 pounds of ground indigo,
5 or 6 gallons of strong iron liquor,
2 pounds of orpiment, and
8 gallons of water thickened with British gum.

He gives also the subjoined table of the proportions of water or mucilage with which this mixture, containing two pounds of indigo to the gallon, may be diluted to furnish, along with the original mixture itself, eleven shades or gradations:—

No.	Quantity by measure of above mixture.	Quantity by measure of water or gum-water.	Quantity of indigo in one gallon of the mixture. lbs.	oz.
1	1	0	2	0
2	1	½	1	5¼
3	1	¾	1	3¼
4	1	1	1	0
5	1	2	0	10¾
6	1	3	0	8
7	1	5	0	5¼
8	1	7	0	4
9	1	9	0	3½
10	1	12	0	2½
11	1	16	0	1¼

COMBINATION OF DIFFERENT STYLES.—All the preceding styles are practised in printing cottons or calicoes, and most of them apply, with certain modifications, to the printing of woollens, silks, and mixed stuffs. On the other hand, the peculiar process termed the *mandarining style*, is applicable only to silks, woollens, and chalis, or stuffs that are composed entirely of animal fibre, and therefore, before proceeding to explain it, some account may be given of the principal modifications required in applying the styles already enumerated to fabrics of that description. At the same time, before concluding the subject of calico-printing, properly so-called, one or two illustrations may be given, to show how the different styles are usually combined, in producing a variegated design on the same piece.

To produce a pattern, for example, in black, red, brown, green, and yellow on a white ground, the following process may be adopted, which is susceptible of a great variety of modifications, and is a combination of the madder style with a topical brown and with steam colors:—First, the cloth is printed by the three-color machine in the following manner: with iron liquor, for black, by the first roller; with red liquor by the second roller, and with catechu brown by the third roller. The cloth is then aged for two days, dunged, dyed in the madder beck, and cleared. Lastly, it is printed or *grounded in* by the block with the mixtures for steam-green and steam-yellow; then steamed, aged, and washed.

By a similar series of operations, a design may be imprinted in black, brown, lilac, pink, green, blue, orange, and yellow, on a white ground. The cloth, in this case, is first printed by the four-color machine, with iron liquor of two strengths, one for the black, the other for the lilac; with red liquor for the pink, and with the mixture for catechu brown. After being aged, dunged, dyed with madder, and cleared as usual, the cloth is printed by the block with the mixtures for steam-blue and steam-yellow, and then steamed in the ordinary manner. To produce the orange, the steam-yellow is printed on a part of the pink, and the green results from the mixture of some of the yellow with the blue.

Again, the following method of procuring a design in black, purple, two shades of red, two shades of buff, green, and yellow on a white ground, is an example of the combination of mineral colors with madder and steam colors topically applied:—In the first place, the cloth is printed by the four-color machine with the mordants for black, purple, and two reds; it is then aged, dunged, dyed in the madder beck, cleared, and dried. It is next printed either by the two-color machine or by blocks, according to the design, with buff-liquor of two strengths, thickened with starch or British gum; then aged, rinsed in milk of lime to raise the buff, rinsed and dried. Lastly, it is printed by blocks with the mixtures for steam-blue and steam-yellow, aged, steamed, and rinsed.

It is evident that the resist and discharge styles may be combined with these or similar processes, to give still greater variety to the pattern; so that, to procure a single variegated design, almost all the different styles enumerated may be applied simultaneously or successively to the same fabric; and it is by their skilful combination that the ingenuity of the calico-printer is displayed, and those wonderful results are produced which exhibit the boundless resources of his art, and constantly astonish and fascinate the world with striking novelties, which, in their endless variety, almost rival the kaleidoscope.

PRINTING OF WOOLLENS, SILKS, AND MIXED STUFFS.—The calico-printer has not often to practise his art on linen goods, or on fabrics of mixed cotton and linen; and when, in particular cases, he requires to do so, he operates on vegetal fibres of nearly the same character and constitution in both cases, so that the processes already described may be regarded as applicable either to cottons or linens, or fabrics in which the two are combined. The case is somewhat different, however, when he wishes to imprint a pattern on a tissue composed of the animal fibre, which manifests a much stronger affinity for most colors, and which, in some important particulars, requires a considerable modification in the manner of treatment. This animal fibre, moreover, according as it presents itself in the shape of wool or silk, renders necessary some distinguishing peculiarities in the mode of treatment; and when, again, woollen or silk fibres are combined with cotton or with each other in the same stuff, a still further modification is required to adapt the relations of the coloring matters and mordants to the mixed fabric.

As a general rule, the madder process, which is so extensively employed in the printing of calicoes, cannot be conveniently applied to the animal fibre, because it involves, in one part of the operation, the total immersion of the goods in the dye-stuff, which, in the process with calicoes, is afterwards easily washed off, except where the mordant has been applied; but such is the attraction of the animal fibre for coloring matters, that even where the mordant has not been applied, the color strongly adheres, and, in the case of woollen goods in particular, the fabric cannot be restored to its original purity. In some processes of silk printing, the madder style is applied; but not without much difficulty and precaution. No mineral coloring material, except prussian blue, is applied to silks or woollens; and hence, in default of having recourse to the madder style, the fixation of the colors imprinted on these tissues can only be effected, in general, by the process of steaming.

Till lately, the printing of silken and woollen stuffs, delaines, chalis, and other mixed fabrics, was confined to the block; but the great extension which has been given to this department by the discovery and improvement of the steaming process, as well as by the great improvements effected in cylinder-printing, has led to the general substitution of the latter method. The press machine and the perrotine are also largely employed in printing these fabrics. They are generally steamed with the lantern, the drum, or the chamber, in which the different parts of the goods are preserved from contact with each other, whereas, in steaming with the column, the fabric is coiled upon itself. In the steaming of calicoes, this is generally attended with no inconvenience, but the fibres of wool and silk have too much attraction for the colors to be treated in the same manner without contracting folding stains, or as the French writers express it, *rapplicages.*

Having made these general remarks with reference to the application of the processes of calico-printing to stuffs consisting, either wholly or in part, of the animal fibre, the Editor will now proceed to point out very briefly, the principal modifications of treatment required for each in particular—namely, first, for woollens; second, for a mixture of wool and cottons, such as delaines; third, for silks; and lastly, for chalis, or a mixture of wool and silk.

Printing of Woollen Stuffs.—The great attraction which the fibre of wool has for coloring matters, while, on the one hand, it renders the madder process inapplicable to woollen stuffs, enables the printer, on the other, to dispense with that preliminary mordanting which is in general given to calicoes, even to prepare them for steam-colors. The very same circumstance, however, requires that the greatest care should have been taken in the bleaching or sulphuring of the wool, and more especially in the *azuring* which constitutes a part of that process. If salts of copper or tin are present, these will infallibly combine, under the action of the steam, with the sulphur adhering to the wool, unless it has been bleached in the most perfect manner, and spots or discolorations will be found after the steaming, which will be ruinous to the whole process. The printer's attention is therefore directed to the method of bleaching woollen goods, described at page 325, as particularly adapted for goods intended for very delicate printing. CHEVREUL has clearly established that the spots or stains so often observed or woollen stuffs after the steaming, are generally due to the presence of a compound of copper, or, more rarely, to that of a compound of tin with the sulphur of the wool, and that these stains are developed during the steaming, by the mutual action of the wool and a salt of copper in presence of steam.

The quality of the sulphate or acetate of alumina, which is the base of many steam-colors, must also be taken into consideration. Sometimes ordinary alum is used, sometimes acetate of alumina ; and though it is of little importance in the printing of calicoes whether the acetate of alumina has been prepared directly, or by the double decomposition of alum and acetate of lead, it is different in the printing of woollen goods; for that which is derived from the acetate of lead, *always retains a certain quantity of the sulphate of lead*, which, according to the nature of the color, may act on the wool, and give it a brown tint, by reason of the sulphur which it contains. Persoz, proceeding on certain experiments made by himself, strongly advises the printer to use only pure alum, and to add, in the cold, to each thickened color, the quantity of acetate of potassa, soda, or ammonia, necessary to render the alum cubical, and capable of yielding its base to the stuff by the effect of temperature alone. He says it is best to employ the acetate of ammonia in all cases where the color is not acted on by the ammoniacal salts, and the acetates of potassa and soda in all other cases.

But the principal difference between the printing of woollen and cotton goods, consists in the composition of the coloring mixtures applied. The woollen fibre resists the action of acids better than cotton, and hence in the mixtures for steam-colors for woollen goods a greater proportion of free acid is introduced, which has the effect of dissolving the lake, or the oxide of the mordant, and thus of producing a more intimate and more uniform fixation, imparting at the same time a higher lustre to the shades. It is for this reason that in mixing steam-colors for woollens, a considerable quantity of tartaric or oxalic acid is almost always employed, whether the mordant mixed with the color is perchloride of tin, protochloride of tin, or alum. At the same time, it is certain that even insoluble bodies, such as charcoal powder, often adhere firmly to wool, and dye or stain it a durable and brilliant color without undergoing the process of solution at all. The most vivid colors on wool are generally obtained by protochloride of tin, with either oxalic or tartaric acid. To show the composition of the mixtures for such colors, a few examples may be given.

The *reds* for woollen stuffs are all formed with cochineal and preparations of tin. Thus for a poppy-red, take one gallon of cochineal liquor, made with two and a half pounds of pulverized and prepared cochineal ; thicken, hot, with a pound and a quarter of starch, and while still tepid, add half a pound of oxalic acid, and one pound of a composition formed by adding two ounces of tin to nine ounces of hydrochloric acid mixed with five ounces of nitric acid.

For a *fine red*, Persoz gives the following :—Boil for five minutes in one gallon of water five pounds of crushed cochineal; thicken with half a pound of starch, and when the mixture has been well boiled, withdraw it from the fire and dissolve in it one pound of oxalic acid, and ten ounces of gum arabic; when cold, add seven ounces of chloride of tin at 106° Twaddell.

Steam-yellows for woollens are formed like the yellows for calico, by decoctions of Persian berry, quercitron, or weld, and have generally the oxide of tin along with alumina for their base. Thus, for an orange yellow, take one gallon of decoction of Persian berries at 14° Twaddell; thicken with two pounds of starch, and add to the mixture ten ounces of alum, eight ounces of chloride of tin, and two and a half ounces of oxalic acid.

Two kinds of *blue* are in use for printing on woollen stuffs; the one formed with carmin of indigo—soluble indigo—the other with the ferrocyanide of potassium. Both have alumina for their base, and to promote its solution not only oxalic acid, but likewise a certain proportion of tartaric acid is introduced. To fix prussian blue on wool, the red cyanide is decomposed by a suitable proportion of tartaric acid to set free the cyanide of iron, and a preparation of tin is added, the object of which is not so much to fix the color, as to give it that fine shade known by the name of *royal blue.*

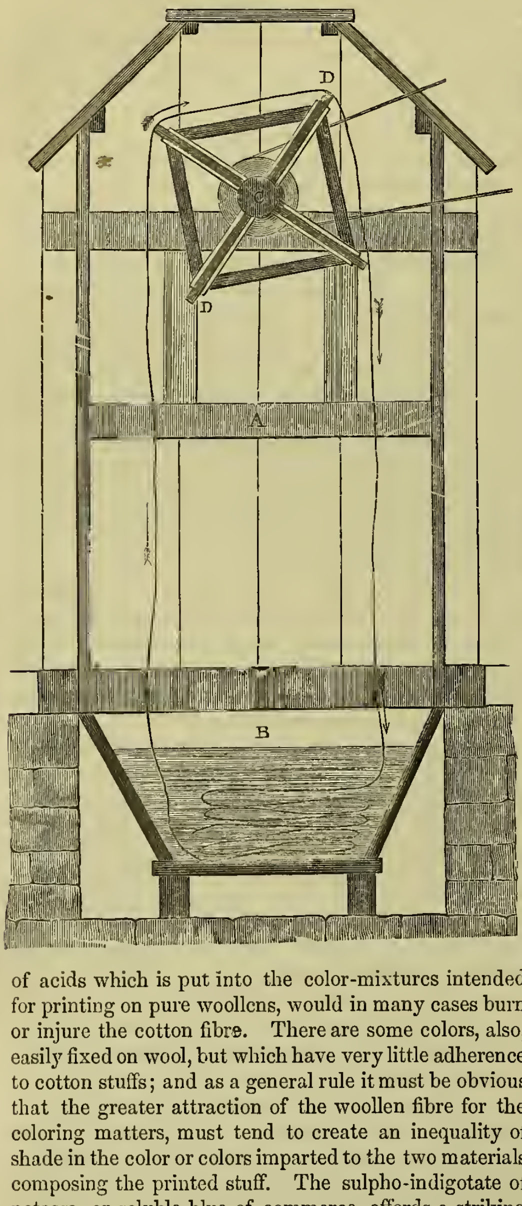
For a good *indigo-blue*, dissolve in one gallon of warm water five ounces of the soluble indigo of commerce; thicken with three and a half pounds of gum, add four ounces of alum, five ounces of oxalic acid, and three ounces of tartaric acid.

For a *prussian blue*, in one gallon of water dissolve twelve ounces of alum, and one pound of oxalic acid; thicken with seven and a half pounds of gum, then add to the tepid mixture half a pound of chloride of tin, two and a half pounds of ferrocyanide of potassium, and twelve ounces of nitrate of iron at 76° Twaddell.

Woollen goods are sometimes steamed at two operations, to prevent the flowing of the colors by a too prolonged exposure to the aqueous vapour; but goods printed with detached figures, are generally exposed to a single steaming of forty to fifty minutes' duration. The washing and drying of the woollen stuffs, after being printed and steamed, are two operations requiring some management. The ordinary washing machines soak the goods too much, and render the subsequent drying too slow. The best method is, to subject the goods to a rapid wincing in a bath fitted with a reel like that of the ordinary dye-beck, and capable of receiving a very rapid motion. This arrangement is represented in the annexed engraving—Fig. 408. a, is a wooden frame supporting the axis, c, of a reel, d, d, which is put in motion by a pulley at one of its ends; b, a trough filled with water, or, better still, a vessel or compartment placed in running water. The goods being formed into an endless web, are passed over the reel, and the whole apparatus is covered in, so that the water which is thrown off by the very rapid motion of the reel, falls back upon the stuff and promotes the washing. The goods are then rapidly dried by means of the hydro-extractor.

Fabrics of mixed Cotton and Wool.—The printing of the stuffs termed *delaines*, which are formed of a mixture of cotton and wool, presents a problem of greater difficulty than is involved in the printing of either of the fibres separately. This will be obvious when one considers that the composition or mixture of

Fig. 408.



the colors which is most suitable for cotton is less adapted for wool, and, on the other hand, the quantity of acids which is put into the color-mixtures intended for printing on pure woollens, would in many cases burn or injure the cotton fibre. There are some colors, also, easily fixed on wool, but which have very little adherence to cotton stuffs; and as a general rule it must be obvious that the greater attraction of the woollen fibre for the coloring matters, must tend to create an inequality of shade in the color or colors imparted to the two materials composing the printed stuff. The sulpho-indigotate of potassa, or soluble blue of commerce, affords a striking example of a color, which, when printed on delaines, communicates a strong shade to the wool, but only an imperfect coloration to the cotton contained in the fabric; and the mode in which this inequality is corrected, will show how the difficulty is surmounted in most cases. It consists in mixing with the indigo-blue for the wool, a suitable proportion of steam-blue for the cotton, prepared by a mixture of yellow or red prussiate of potassa with tartaric, oxalic, or sulphuric acid, and alum. In one peculiar style of fancy dyeing, the woollen thread only is dyed, and the cotton is afterwards perfectly bleached by exposing the dyed delaines to a dilute solution of bleaching powder.

It has been stated, that cotton goods are generally prepared for steam-colors by a previous mordanting—a preparation which is not required for woollen goods. Delaines, however, are always prepared in this manner, on account of the cotton which they contain, and which, by this preliminary process, is rendered more apt to receive and to retain the colors like the wool itself. These stuffs, before being printed, are always impregnated with binoxide of tin, from the different solutions applied consecutively. They ought, also, to be perfectly bleached before receiving the mordant, for otherwise the white parts remain dull, and produce inequalities in the shades. The usual preliminary process with these mixed fabrics, is to pass them on rollers through a cistern charged with a solution of bleaching powder and a little sulphuric acid. The woollen fibre is thus made to combine with as much chlorine as possible, so as not to brown it. The stuff is then impregnated with stannate of soda, and run through *dilute* sulphuric acid to fix the oxide of tin. The perfection of the work depends chiefly on this process.

The steaming is performed in the same manner as for woollens, and either by the column or chamber, but generally for a shorter period. This is a point, however, for which it is impossible to lay down any fixed rule, as the time must vary according to the manner in which the steam is applied, the dimensions of the chamber, and the quantity of acid in the mixtures. With a considerable quantity of acid, such as is best adapted for woollen stuffs, the fibres of the cotton especially become weakened by too long exposure.

The following receipt is given by Persoz for an *amaranth* mixture, suited to this kind of fabric:—Boil two and a half pounds of powdered ammoniacal cochineal in a gallon of water; thicken with two pounds thirteen ounces of gum-Senegal; add half a pound of alum, and two pounds of bichloride of tin at 125° Twaddell. This amaranth is also adapted for cylinder-printing on wool.

For a *Turkey yellow*, take a decoction of three pounds of Persian berries in a gallon of water; thicken with fourteen pounds of starch; boil and add one pound of protochloride of tin.

For a *dark double blue*, dissolve in one gallon of warm water two and a half pounds of ferrocyanide of potassium; add, when tepid, six ounces of oxalic acid, and seven ounces of alum; thicken with one gallon of gum-water containing eleven pounds of gum, and to which has been added five pounds of soluble indigo-blue.

Printing of Silk stuffs and Chalis.—The printing of steam-colors on silks, is similar to printing on woollens, except that the acids must be used more sparingly. In this respect, indeed, the composition of the color mixtures for silks, is more analogous to that which is required in calico-printing; but, on the other hand, the silk and the wool have similar relations of affinity for the coloring matters. With two exceptions, which are resolvable into one, the only preliminary operations to which silken cloth intended to be printed is commonly subjected, are, first, boiling in a solution of soap and carbonate of soda, to remove the *gum;* second, passing through dilute sulphuric acid; and third, washing and drying. Or, CLAUSSEN'S process, given at page 326, may be adopted. The two exceptional cases above referred to, are when the silk is to be printed with a French blue or green; to prepare the goods for these colors, they are immersed during fifteen to twenty minutes in a bath of acetate of alumina at 4° Twaddell, and then dried on a steam-drum to expel the greater part of the acetic acid.

The colors to be printed on silks are always mixed with as little acid as possible, and do not require quite so much thickening as those for wool. No precise rule can be given for the duration of the steaming, which must be regulated according to the quantity of acid in the colors, and other circumstances, but it is considerably less than for woollens. The lantern is well adapted for the steaming of silks.

For the *reds* imprinted on this fabric, cochineal is generally employed; sometimes, however, they are derived from the dye-woods, using oxalate of potassa instead of the oxalic acid which figures in the colors applied to wool, as the silken fibre would inevitably be injured by the free acid. *Blues* for silks are derived either from the carmin of indigo, or from the cyanides, using with the former an aluminous base, and with the latter a base of tin. For *steam-yellows* on silks, the Persian berry is generally employed; but the quercitron yellows are unquestionably more lively and brilliant.

The following may be given as an example of a common *steam-blue* for silk:—In one gallon of boiling water, dissolve three and a quarter pounds of carmin of indigo, seven ounces of alum, one pound of tartaric acid, and thicken with five pounds of gum-Senegal.

For a *poppy-red*, thicken a decoction of two pounds of cochineal in a gallon of water, with one pound of starch; boil, and add, when tepid, two and a half ounces of chloride of tin, and five ounces of binoxalate of potassa in powder; when cold, introduce two and a half ounces of red spirits.

The steam-colors for chalis, or mixed fabrics of wool and silk, are necessarily similar to those applied to silks individually, because, if the acids were present in a free state, and in the same proportion in which they are mixed with wool colors, the texture of the silk in the fabric could not fail to be weakened. When this precaution is taken, the printing of mixed fabrics of silk and wool, both of which are animal fibres, and have nearly the same affinity for the coloring matters, is not attended with the same difficulty as that of delaines, or a mixture of wool and cotton.

Madder Style for Silks.—Though the coloring matter of the common dye-stuffs adheres with too much tenacity to the unmordanted woollen fibre, to render possible the application of the madder style to woollen goods, yet it is sometimes applied to silk stuffs, and was practised extensively for silk handkerchiefs before the introduction of the method of fixing by steam. The general process is the same in its leading features as for cotton goods, but the delicate nature of the fibre, and its strong attraction for coloring matters, render it considerably more difficult.

To illustrate the slight peculiarities of treatment required in applying the madder style to this fabric, a short account may be given of the method of printing a *red and black* design on silk handkerchiefs.

As it is not without much difficulty that the white of the silk can be brought back to its original purity when it has been soiled or discolored by the dyeing operations, great care must be taken, in the first place, to see that stuffs of this description which are intended for printing be perfectly free from every substance susceptible of fixing the coloring matter on parts which are intended to retain their original whiteness, either wholly or in part. There are few printers, therefore, who do not scour and remove the gum for the white grounds on which they intend to operate, by passing them into a bath of soft soap. When the stuff has been thus treated and dried, it is printed first with a mordant for the black design, consisting of iron liquor—acetate or crude pyrolignite of iron—at 10° or 11° Twaddell, thickened with starch. After an ageing of two or three days, the goods are printed with the red liquor for the red design—acetate of alumina, marking 11° Twaddell, and thickened with roasted starch. It is of essential importance to print-on no more mordant than is strictly necessary, for if it be ever so little in excess, it will pass over on the white parts, which will then take on the color strongly. When the printing is finished, the goods are again aged for two or three days, and the next operation is the fixing of the mordants, which, with calicoes, is usually performed with dung or dung substitute, but must be performed in this case by passing the goods through a bran-bath, with or without a certain proportion of sumach. When this substance is added, it is introduced into the clear decoction after the bran has been boiled, and when the bath has fallen to the temperature of 140°. Thirty-five pieces of the silk, divided into five parcels, are passed into this bath, and are left in it for twenty-five to thirty minutes; they are then washed at the wheel. For twenty parcels of seven handkerchief-pieces each, about twenty-six pounds of bran, with three pounds of sumach, are used; the bran decoction is divided into four portions, which are added successively to the bath in proportion as it becomes exhausted.

Perhaps the double arseniate of lime and potassa might be employed with advantage to fix the mordant better, and would only involve the necessity of scouring the goods. After the fixing with bran, the goods are winced in the dye-beck, and the quantity of garancin employed is calculated according to the weight of the raw goods, in the proportion of about an ounce and a half to the handkerchief, or about thirteen or fourteen pounds for one hundred and forty handkerchiefs, the number usually operated upon at one time. To this dye-stuff is added at least double its weight of bran, with a small quantity of vinegar, both to correct the water and to prevent the staining of the white parts. The wincing in the dye-beck is continued for fifty to sixty-five minutes, beginning with a temperature of 120°, and rising progressively to the boiling point. The goods are then cleaned, and submitted to the action of a soap-bath, heated to 160°, to purify as much as possible the unmordanted parts, and to increase the brightness of the colors.

Mandarining Style, for Silks and Chalis.—This most peculiar style, which is so called from certain silk stuffs termed *mandarines*, can only be applied to woollen or silk fabrics, and differs entirely from any of the numerous processes practised with cotton goods. It was much in use for handkerchiefs and other silk goods, before the method of printing with steam-colors was carried to that degree of perfection which it has now attained.

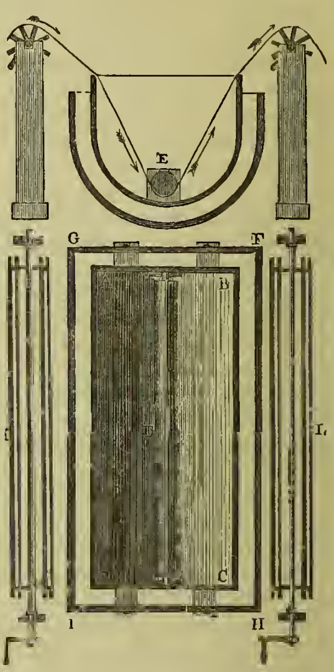
The principle of this curious process is based on the action exerted by nitric acid on colors and on every textile fibre of an animal nature. By exposing a silk or woollen stuff to the action of this acid, more or less diluted, a yellow or orange color, similar to that which it imparts to the skin, is communicated to the cloth, proceeding from a peculiar substance formed through the decomposition by the acid of a portion of the fibre of the cloth itself. The same effect is produced when the cloth has been previously dyed with certain colors, and thus, by printing a resist paste on the parts intended to be reserved, and then passing the goods through the acid, very beautiful and elegant effects are produced, which admit of considerable variety. The mandarining process may therefore be regarded as a kind of combination of the resist and discharge styles.

The operation of the resist in this case is purely mechanical. Its office is simply to preserve the cloth, at those parts on which it is applied, from contact with the nitric acid. Its composition and thorough application to the stuff are, therefore, points of the highest importance, for, should it not act with perfect efficiency, the whole effect would be destroyed. The resist most commonly employed consists of fifteen parts of resin melted into intimate mixture with two parts of suet; or a still better is formed by melting and passing through a strainer a mixture of suet and stearic acid. One or other of these compositions is printed-on with the hand-block; and for this purpose they require to be softened by heat, and kept at a certain uniform temperature, which is accomplished by means of the arrangement represented and described at page 687. The printing-block must also be heated after each impression, by placing it in contact with a part of the apparatus appropriated for that purpose.

As far as possible, the parts on which the resist is printed should form the subject or pattern, and the other parts the ground. If such resists have been printed on a white stuff, which is then passed into nitric acid, the design obtained, on dissolving off the resist, will be a white figure on a yellow ground. These resists may be employed, however, not only to protect certain parts of the stuff from the action of the nitric acid, but also from that of any coloring liquid which is capable of dyeing the stuff at a temperature that will not melt the resist. Very elegant and various effects are produced in this manner. Thus, after printing a part of the design with the resist on a white stuff, the latter may be passed into the blue vat, which will produce a blue ground with a white figure covered over with resist. Allowing this resist to remain on the stuff, and printing the same composition on a part of the blue ground, then passing the goods through the acid, the blue will be discharged from the uncovered parts, and a yellow ground will be obtained, relieved with blue and white figures, the former on the parts covered by the second printing, and the latter on the parts to which the resist was first applied. There is nothing to prevent operating in the same manner on fabrics colored in any other way, or simply mordanted, and afterwards dyed.

The nitric acid to be used in this process is put into a sandstone trough, A B C D—Fig. 409—to the ends of which, A B and C D, boards are fitted on the inside, and holes are made in these boards to receive the journals of the roller, E, which is adjusted lengthwise in the trough about an inch from the bottom. To raise the acid to the proper temperature, this trough is placed in another, F G I H, which may be constructed of wood or copper, and performs the part of a water-bath, the interval between the troughs being heated by steam or otherwise. On each side, and parallel to the axis of the troughs, are two reels, K, L. The goods are coiled upon one of these reels, L, from which they pass into the trough under the roller, E, and then over the other reel, K, as shown in the sectional figure. Motion is given to the reels by the handles, H, I.

Fig. 409.



The acid is diluted with more or less water, according to the kind of effect to be produced. As a general rule, it ought to be used as weak as possible, increasing its power, if necessary, by a higher temperature; but to avoid the risk of melting the resist, the temperature must not be raised beyond 100°. To discharge very strong colors, the nitric acid of commerce is diluted with only half its volume of water. Sometimes this proportion is reversed, but, generally, the water and acid are mixed in about equal proportions. The time of the immersion must vary according to the strength of the acid, the nature of the color to be discharged, and the temperature of the bath. It is for the operator, therefore, to determine the proper time by a preliminary experiment on the small scale. It is never prolonged beyond one minute at most. Instead of a single roller placed at the bottom of the trough, it would probably be better to have two or three, to render more regular throughout the contact of the stuff with the liquid.

After passing through the nitric acid, the goods must be immediately rinsed; and for this purpose another trough or vat, containing a mixture of water and chalk, is placed immediately under the roller, K, or they are made to fall into a stream of cold water. They are then boiled in soap-water, containing a little carbonate of soda, at the rate of two pounds of the former and four ounces of the latter for each piece of thirty yards. In this liquor they are winced for half an hour, which removes the fatty or resinous resist, and communicates an orange tinge to the yellow ground produced by the passage through the acid, or the *mandarining.* They are now rinsed again in cold water, then passed through hot water, rinsed a third time and dried.

Such is a general outline of this peculiar process, which admits, however, of considerable variety in the modes of its application, and is indeed one of the most striking illustrations of chemical ingenuity in the arts, as a few examples will show.

In the first place, a white figure is obtained on an orange ground, by simply printing the resist on the white stuff and mandarining.

In the second place, a figure in red, rose, blue, green, or any color, in short, capable of undergoing the boiling with soap and carbonate of soda, may be obtained on an orange ground, by first of all dyeing the whole piece of the color required for the figures, then printing-on the resist, and mandarining.

Thirdly, when the color desired for the figure is too delicate to stand the action of the boiling in soap, the difficulty is overcome by first padding the goods with a mordant, and after having fixed this in the usual manner, printing-on the resist. The goods are then passed through the nitric acid, to which a certain proportion of tartaric acid has been added, to assist in dissolving off the mordant from the parts which are not protected by the resist paste. This operation is followed by a rinsing and cleansing with soap, when it only remains to dye the goods in a bath of the required color, and those parts alone on which the mordant has been reserved will take the dye.

In the fourth place, a combination of white and blue figures on an orange ground may be obtained in the manner already described.

Fifthly, a white figure on a dark green ground is obtained by first printing-on the resist; then mandarining; then dyeing in the indigo-vat to produce a green by the combination of the blue with the mandarine yellow; lastly, boiling with soap and alkali to impart to the yellow of the green the orange tinge, by which it is darkened to the desired shade.

In the sixth place, for white, blue, and orange on a dark green ground:—

1. Print on the resist for the white;
2. Dye light blue, wash, and dry;
3. Print on the resist for the blue;
4. Mandarine, wash, and dry;
5. Print on the resist for the orange;
6. Dye dark blue to produce with the orange a dark green ground;
7. Clean and dry.

Lastly, it may be observed that instead of using nitric acid *per se*, this acid may be associated with iron salts or other saline solutions capable of combining with the stuff, and in this manner a variety of figures will be obtained on a bronze or other ground. Thus, for the bronze or solitaire style by this process, the mandarining mixture is one gallon of nitric acid of specific gravity 1·17, mixed with three pints of solution of nitrate of iron of 1·65 specific gravity; or a darker tint may be obtained by increasing the quantity of nitrate of iron.

THEORY OF THE FIXATION OF COLORING MATTERS IN DYEING AND PRINTING.—There are two methods of coloring stuffs which must not be confounded with each other. By one of these, as in the case of the oil-painter, the coloring matters, lakes, *et cetera*, are mixed with gums or varnishes to make them into a color which is applied to the stuff, and which, on drying, adheres to it. Whether these coloring matters are mixed with a fat varnish, drying oil, gluten, white of egg, starch, or mucilages, the result is always the same; but this operation, which is purely mechanical, and which may be performed on every kind of fabric, will only occupy the printer's attention so far as relates to the discovering of that glutinous body which is most capable of rendering this or that colored substance adherent to such or such fabric. By the other method, the coloring matters, brought to the proper conditions, are deposited and then fixed on the goods in such a manner as to be incorporated with the fibre, and only to be capable of being detached from it by the intervention of a more or less powerful chemical agent; but some of them—and in this number are several substances of the organic kingdom, such as indigotin, carthamin, curcumin, and among the mineral colors, the oxides of iron, chromium, lead, *et cetera*—only require to be applied on the goods; whilst a greater number of others, such as madder, cochineal, Brazil and Campeachy woods, quercitron, and weld, unite with the different fibres only by the co-application of auxiliaries, which are designated by the name of *mordants;* it is in consequence of this difference that all who have written on dyeing have divided coloring matters into *those which adhere to the goods of themselves;* and *those which can only be fixed by the co-application of mordants.*

To discover the cause in virtue of which the different colored bodies unite with the textile fibres of cotton, wool, and silk, to such a degree as to form with them one body; to explain how it happens that one and the same substance has not the same aptitude for each of these fibres—such is the question which first presented itself to the scientific men who devoted their attention to the application of colors, and the solution of which is more especially important to the art of dyeing, of which the *printing* of fabrics is but a particular case. HELLOT and LE PILEUR D'APLIGNY, MACQUER, BERTHOLLET, BERGMANN, and CHEVREUL, who are justly entitled to rank as high authorities on this subject, have given forth different opinions on this point. The first two saw in the fixation of the colors on the goods only a purely mechanical operation; the last four, on the contrary, only an operation purely chemical.

Opinions so opposite, and sustained moreover by such high authorities, demand, for these reasons alone, a searching inquiry into the truth; but a new motive to this inquiry is found in the views and arguments published by one of the most distinguished scientific printers in Great Britain, Mr. WALTER CRUM of Glasgow, who, in a recent paper, tends to revive the opinion of HELLOT and LE PILEUR D'APLIGNY.

To explain the difference between fast and fugitive colors, Hellot attributed to the fibre of wool in particular, pores susceptible of opening and closing, in which the coloring particles lodge. When fixed or glued there by the astringent substance which is commonly made to intervene in the operations of dyeing, and which, according to him, would form a coating, the color is *fast;* in the contrary case, it is *fugitive* or *fading.* Hence he affirmed that what he termed the *invisible mechanics* of dyeing consist in dilating the pores of the body to be dyed, to deposit therein the particles of a foreign substance, and to retain them by a kind of coating, which neither rain-water nor the rays of the sun can injure; to choose the coloring particles of such tenuity that they may be retained sufficiently encased in the pores of the stuff, opened by the heat of boiling water, then shut again when cold, and further coated with the kind of cement which is left in these same pores by the salts chosen to prepare them. Whence it would follow, that the pores of the fibres of woollen stuffs should be cleaned, enlarged, coated, then closed, that the coloring atom may be retained, not unlike a diamond in the bezel of a ring. He affirmed that there are no coloring ingredients of the class termed *fast* which have not, more or less largely developed, an astringent and precipitating property; that this suffices to separate the alumina—one of the salts which are employed in the preparation of the wool before dyeing it: that this earth, united with the coloring atoms, forms a kind of lake similar to that of painters, but infinitely finer; that in the bright colors, such as scarlet, for which alum cannot be used, it is necessary to substitute for the earth of that salt, which is always white when the alum is well selected, another body which may furnish to these coloring matters a base also white; that pure tin affords this base in the dyeing of scarlet; that when all these minute particles of earthy lake are introduced into the dilated pores of the article, the coating which the tartar—another salt employed for its preparation—has left therein, serves to cement these atoms in the pores; and that, lastly, the closing of the pores by the cold serves to retain them there.

Consistently with these ideas, Hellot suggested that perhaps the colors called fugitive are only so because the material to be operated upon is not sufficiently prepared; so that the coloring particles being only deposited on the smooth surface, or in the pores, the capacity of which is not sufficient to receive them, it is impossible that they can resist the least washing. If means were discovered of giving to the coloring parts of the dye-woods the astringency which they want, and at the same time the wool were prepared to receive them, as it is prepared, for example, to receive madder-red, he conceived that one might succeed in rendering these woods as useful to the dyers of fast colors, as they have hitherto been to the dyers of fugitive colors.

Le Pileur d'Apligny lent the support of his talents and of his pen to the theory of Hellot; but instead of confining himself, like the latter, to study only wool in its relations with coloring matters, he regarded, under the same view, silk, cotton, hemp, and flax; and to render this theory more probable, he was careful to precede it by considerations on the texture of the different fibres. Wool, according to him, is composed of an infinite number of filaments, of the nature of hairs, and containing like them a marrow or fatty substance, being nothing but pipes perforated in their whole length, and laterally, with an infinitude of orifices, by which the foreign substances reach the heart of these tubes previously deprived of their marrow; and this fibre being, of all the textile fibres, the most porous, is from that very circumstance the easiest to dye, and is at the same time that which absorbs the most coloring matter Silk is only a series of molecules of dried animal jelly, which, shrinking more or less by its desiccation, and thus giving rise to inequalities, producing pores which exist only at the surface of the thread, admit only colors extremely dilute and in very small quantity, which explains, according to him, why silk is one of the most difficult fibres to dye. The staple of cotton, being much finer than that of wool, but hollow like it, filled with marrow and furnished with lateral apertures, is also more difficult to dye, because it admits into its pores and interior only colors much more attenuated and in less proportion. The threads of flax and of hemp, being finer still than the preceding, are equally porous. From these considerations, d'Apligny arrived at the conclusion, that without gratuitously assuming the existence of any chemical affinity between the colored infusions and the goods to be dyed, one can easily understand why that which communicates to wool a scarlet color, does not give the same hue to silk, and imparts no color to cotton. On this theory, it gives to silk only a very dirty color of port-wine lies, because the particles of cochineal form a lake with the oxide of tin diffused in the dye-vat, which lake the pores of the wool are sufficiently large to lodge, but those of the silk, being too small, cannot admit it—they admit only the cadaverous parts of the cochineal more minute than those of the lake, because they are simple —but almost all the color of which has been absorbed by the oxide of tin. Cotton, in its natural state, admits none of it into its pores; but, for the same reason, it receives, like silk, a brownish-red color when it has been properly deprived of its gum. On this principle, it further results from the different texture of the substances to be dyed, that each of them takes different shades in the dyes which can penetrate their pores, though the same processes are employed to dye them. D'Apligny adds that this observation holds good even in regard to stuffs differently woven, although of the same material; as the different modes of manufacture produce in a greater or less degree a closing of the pores of the stuffs, which makes them receive more or less of the colored particles. It is this closing, he says, which produces the effect that a cutting of scarlet cloth is white in the interior, the colored molecules being too coarse to penetrate into it, which does not happen with other dyes, for which the goods are alumed before dyeing.

These views, as d'Apligny himself states in his preface, are only a development of the ideas of Hellot on the dyeing of woollens.

Dufay, in 1737, and Bergmann, in 1776, were the first to put forth a different opinion on this subject, and to recur to chemical affinities to explain the property possessed by a coloring matter of uniting with this or that stuff in preference to another. BERGMANN especially, in his work on Indigo, expresses himself clearly on this subject, by saying that, if the sulphate of indigo is attracted by preference, and in greater proportion by wool than by silk, the cause of this must be found in the difference of affinity which exists between these two fibres; one of which, that of the wool, is sufficiently powerful to take from the dye-bath all its coloring particles, whilst the other, that of the silk, being much weaker, can only diminish the proportion of the colored molecules which exist in such a bath.

MACQUER, to whom the art of dyeing owes the most important works which have been written on the means of fixing colors, seemed, at least at one period of his life, to lean to the ideas of HELLOT; but in 1778, in the article DYEING of his *Dictionnaire de Chimie*, he gives forth clearly a quite different opinion; for after reciting some peculiarities essentially distinctive to the coloring matters which produce hues as varied in their shades as in their intensity, by varying the fibre on which they are impressed, this skilful chemist adds:—The most general conclusion which appears to result from these particular details, is, that wool and all animal matters are, of all substances that admit of being dyed, those which lend themselves most readily to the action of the dye; that linen and all matters purely vegetal are, on the contrary, those which it is most difficult to dye, which take the least number of colors, and further, which take them on less fine and less firm; lastly, that silk and other substances which would appear to hold a middle place between matters purely animal and those that are purely vegetal, hold also the middle place in this respect in dyeing operations. He does not deny that this greater or less facility of taking and retaining the dye, possessed by different substances, depends in great part on the number, size, and arrangement of the pores, and on their proportion to the colored particles of the dyeing substances; but this, he conceives, is not the only cause of the great differences which one observes in the relative nature of the substances to be dyed; and he urges the following fact, which is very constant and well known in dyeing, as affording satisfactory evidence of the truth of this:—

If, after aluming as much as possible a pound of wool and a pound of silk, each of them is afterwards dyed separately in a cochineal bath, they will both take a very beautiful and very fast crimson; but with an equal quantity of cochineal in each bath, the color of the wool will be infinitely fuller and more intense than that of the silk: this difference is so great, that one can succeed in giving to the crimson of the silk as much intensity as to that of the wool, only by employing more than double the quantity of cochineal; that is to say, it requires two and a half ounces of this ingredient to give to the pound of silk as full a crimson as that which the pound of wool takes with a single ounce of the same substance. And it is impossible to say, with D'APLIGNY, that this arises from the pores of the silk being much finer than those of the wool, so that it can only take the finest coloring parts of the cochineal, whilst the wool takes them all, because its pores are larger or more numerous; for if this were the case, there ought to remain much color in the bath after the silk has absorbed all that it can, and refuses to take on more: now, this, as MACQUER justly remarks, is not what happens; it is always the case, on the contrary, that the silk, which has been dyed with two and a half ounces of cochineal per pound, leaves its bath as clear, and as much exhausted of color, as that of the wool which has been dyed with a single ounce of cochineal.

There must, therefore, be some other cause than the size and arrangement of the pores, which exerts a powerful influence in the difference of the effects that are observed in relation to the nature of the substances which receive the dye. The pores, by multiplying the surfaces and points of contact of the material to be dyed with the tinctorial substance, 'cannot fail, says this distinguished chemist, to facilitate considerably the application of the latter; but it is not a simple encasing of the colored atoms in the pores, which serve as a bezel to them: there is further, he says, a real adherence of contact, and even a chemical combination of these colored particles with the substance itself on which they are applied; and this adherence is, as in all other combinations, more or less intimate and powerful, according to the nature of the substances which unite together. It is easy to conceive, in fact, that the number and depth of the pores, far from increasing the effect of the coloring particles, is rather calculated to absorb them, to conceal them, and consequently to diminish the intensity of the dye. It is, therefore, chiefly, by being applied on the surfaces, where nothing covers them, that the colored atoms of the dye-stuffs communicate their color to the dyed goods; it is a kind of painting in which the colors are applied, and adhere to the surfaces by the effect of contact, and in virtue of the greater or less affinity which they have with the particles of these same surfaces, according to their respective nature.

In treating the same subject, BERTHOLLET has introduced into the question no new argument; but, in his Elements of the Art of Dyeing, he groups all the important facts of this art, and draws from them a series of conclusions, all of which tend to induce the opinion that the phenomena presented by it are dependent on chemical affinity.

Of all chemists, M. CHEVREUL is the one who has searched most deeply into this important matter; and in comparing the general phenomena of dyeing with those which natural philosophers and chemists generally consider as dependent on molecular forces, the causes of chemical action, he arrives at the conclusion, that the first are of the number of those which take place when two or more bodies are in contact, and their combination is effected slowly.

It appears, therefore, that, whilst HELLOT and LE PILEUR D'APLIGNY attribute all the effects produced by coloring matters in the operation of dyeing, to the existence in the fibres of pores or cavities, more or less numerous and spacious, in which the coloring atoms lodge, all the other chemists repudiate this view of the subject, and trace the same effects to chemical affinity.

Nevertheless, the conclusions of MACQUER have a peculiar character, requiring special consideration; while rejecting the opinions put forth by LE PILEUR D'APLIGNY, he does not deny the influence of the pores, and of the nature of the fibres, and lays down the formal proposition, *that the coloring parts apply themselves and adhere to the surfaces of the fibres, by the effect of contact, and in virtue of the greater or less affinity which they have with the parts of these surfaces themselves, according to their respective nature.*

Such were the notions entertained by scientific men on the causes of the adherence of coloring matters to the goods, when the views of Mr. WALTER CRUM were published. According to the experiments of DE SAUSSURE, experiments so full of interest and so well known, chemists were aware that charcoal absorbs gases without altering their nature, in proportions which vary, according to the nature of these gases, its own nature, and its state of porosity. No one is now ignorant of the applications which are daily made of this body in the arts, for decoloring sirups, by freeing them from different substances. It is in connection with this order of facts, and enlightened, moreover, by the theoretic works of the celebrated chemist of Berlin, that Mr. CRUM proceeds to adduce arguments in favor of the ideas of HELLOT. He advances, in fact, after passing in review the different modes of action of porous bodies, that several dyeing operations depend on the capillary action described by DE SAUSSURE; and this opinion he bases chiefly on the result of the microscopic examination of the fibres of cotton which was made by Mr. THOMPSON of Clitheroe, and M. BAUER—this examination having established, that these fibres are formed of transparent and glass-like tubes, which, though cylindrical before their maturity, flatten on the contrary from end to end as they ripen, and then present the aspect of two separate tubes. Mr. CRUM thinks that, since the sides of these tubes permit water to pass through, they must be porous; but he adds, that neither the form, nor even the existence of such lateral perforations have been capable of being discovered by the aid of the most powerful microscope. This, as will be seen, is the hypothesis put forward by LE PILEUR D'APLIGNY, presented under a new form, and with the reserve of a mind essentially experimental. This being assumed, the eminent Scottish manufacturer explains the fixation of the colors in the following manner. He first admits that the mineral base of a madder-dyed color—oxide of iron or aluminum—treated with a volatile acid—*acetic acid*, for example—gives rise to a solution which, when impressed on the fabric, is there gradually decomposed in course of time, abandoning its acid, *just as it would be decomposed in similar circumstances without the intervention of the cotton;* and if this base, deposited on the fabric, remains adhering to it so powerfully as to resist the action of the most perfect washing, it is because the solution, after having penetrated by the lateral openings into the interior of the tubes which compose the cotton, is there decomposed, and the oxide being set free in the narrow passage where it is enclosed, can no longer be disengaged from it. When the cotton, then, composed of *sacs* thus lined with metallic oxide, passes into a madder-bath, or one of any other coloring matter, the latter combines with the metallic oxide by a true chemical action to form a lake, or what is properly called a color.

Such is the theory adopted by Mr. CRUM, and which he endeavors to justify by several arguments. According to his view, for example, by making the adherence of the colors depend on the force of attraction, which unites the bodies atom to atom, one is compelled to admit the disorganization of the fabric, even though experiment proves that cotton wool can be dyed by metallic oxides without its fibre being injured, since it is recovered with all its properties entire, when, by chemical processes, it is deprived of the color with which it has been impregnated. Mr. CRUM imagines that he finds a new proof in support of his view of the subject, in the observations he has made, both by the naked eye and with the aid of the microscope, on the staples of cotton dyed blue, red, and yellow; and whence it would result, that those hues which appear uniformly diffused over the whole surface of the fibres, appeared only, when observed with the microscope, to color the internal side of the tubes, which would be themselves colorless. The coloration of plants offers to him also a subject of comparison, with which he connects the phenomena of dyeing, and, with Dr. LINDLEY, he regards their cellular tissue as formed of small vesicles, the openings of which, though not visible, *must nevertheless exist*, since they are permeable to liquids, and being filled with different tinctorial matters, give rise to the colors which characterize the different organs of plants. Lastly, Mr. CRUM discusses the operations of indigo-dyeing, with the view of proving that there is no chemical combination, in the proper sense of the word, when the coloring matter is fixed on the goods.

Such are, in few words, the principal considerations which this chemist brings to bear on the question. PERSOZ holds a different opinion, and proceeds to examine how far this theory, which, by the author's admission, has several points of resemblance to that of HELLOT and LE PILEUR D'APLIGNY, admits of being supported by the facts on which it is based. The following are PERSOZ's views on the subject:—

According to the first proposition, the acetate of alumina, for example, would be decomposed in presence of the goods, just as if it were free, and experience seems to him to be here opposed to such an assertion. He does not dispute that this salt, free, or in presence of the goods, is composed of acetic acid and alumina, or basic acetate; but that, for equal quantities, and diffused over equal surfaces of cotton cloth, plates of glass, mica, or platinum, and dried, moreover, in the same conditions, this acetate gives up always the same quantity of alumina, is what he finds it impossible to admit. In fact, if the desiccation takes place at a temperature but little elevated, the quantity of the earth, taken from the acetate by the cotton, will be incomparably greater than that which would be liberated on the glass or mica plates; it must be concluded, therefore, that the textile fibre of the cotton exercises a powerful influence on the decomposition of the acetate of alumina. But if any doubts still exist as to the part which the fibre performs in the decomposition of a mordant, the subjoined fact ought, he thinks, to dispel them. A solution of cubical alum, submitted to spontaneous evaporation, yields crystals of *cubical alum;* but if one puts in it, for a certain time, stuffs of silk and cotton, this same solution now furnishes, after undergoing a spontaneous evaporation, nothing but octahedral crystals of alum, deprived as it is by these stuffs of a notable portion of its base.

If from this proposition one passes to that which is, as it were, the foundation of Mr. CRUM'S theory, and according to which the cotton fibre must be regarded as formed of small sacs, capable of being filled with coloring matter, or with an oxide susceptible of afterwards uniting chemically with the dyeing substance of a dye-vat, this will be found not less opposed to all the data of experience. How explain, in fact, that liquids so viscous as the colors thickened with gum or starch, which are printed on fabrics, can drive out the air which exists in the sacs of the cotton fibre, and occupy its place? Must it be assumed that the sacs contain no air, or that they are endued with a very powerful capillary attraction? This view of the subject appears scarcely admissible; nevertheless, it is not the greatest difficulty which this hypothesis presents. The dyer prepares with starch, and with a certain quantity of sulphate of copper, the goods which are to be dyed in the blue-vat, in order to economize the coloring matter of the indigo. According to Mr. CRUM'S theory, this preparation, filling the small sacs, ought to be an obstacle to the dyeing, and yet experience proves, on the contrary, that it favors it. In the same manner, in dyeing Turkey-red, it has been seen that the goods are first impregnated with oily preparations, and afterwards with astringent substances, such as nutgall, sumach, *et cetera,* before interposing the aluminous salt, which serves for a base in this kind of dyeing.

When a cotton fabric is dipped in a chloride solution, or one of sulphate of manganese, and afterwards passed into an alkaline menstruum, oxide of manganese is precipitated, which, according to Mr. CRUM, is rendered insoluble, not at the surface of the fibre, but in the heart of the sacs, where it absorbs a fresh quantity of oxygen, and is transformed into binoxide of manganese, which thus adheres to the fibre; but a fabric, which, by this process, would be charged to the utmost with binoxide of manganese, should no longer be able to attract to it another coloring matter; and, nevertheless, it is so well established that, in such case, it is more than ever fitted for being impregnated with indigo-blue, that advantage is taken of the property possessed by the higher oxides of manganese, to favor the precipitation of this blue, for obtaining double shades by it. It will not be alleged that the indigo adheres only to the oxide of manganese, and that it is sufficient to withdraw this oxide, to cause at the same time the disappearance of the coloring matter which is associated with it, since it is at any time possible, by destroying the binoxide of manganese by means of chloride of tin, to cause the reappearance of the blue with the same brightness and firmness it possesses when it is fixed directly on the goods without the co-operation of this oxide.

Deposited on the surface of a cotton fabric, the sulphate of lead, which is insoluble, is removed by the slightest affusion with water; but, by simply dipping the goods in a milk of lime, one can render it adherent to the fibre without making it pass into the liquid state, and, consequently, without its being capable of penetrating into the vesicles of the fabric.

Lastly, many colors that have little adherence to the goods, even with the co-application of certain mordants, are strongly fixed upon them when the goods are previously prepared with oxide of tin. This oxide, in the same way as the fatty bodies and astringents employed in the dyeing of Turkey-red, should, if the hypothesis now engaging attention be well founded, fill the cavities of the cotton fibre, and so far oppose the introduction and fixation of the colors which are subsequently applied to it.

Passing from this order of facts to another, it is easily seen, on examining attentively a dyed or printed stuff, that the color upon it is always at the surface, and in relief—a fact which nothing can prove better than the facility with which this color is taken off by thickened corrosives. If it adhered to the fabric only by penetrating and filling the vesicles of the fibres, how would a thickened acid be capable of introducing itself into these same vesicles, and removing the oxide? How would the slightest washing be sufficient to clear these cellules of the chemical compounds which would be formed in their interior? On the other hand, does not the great art of producing a lively and brilliant Turkey-red consist in depositing the mordant or the color only at the surface of the goods? If the centre were impregnated with it, the red would become brown, and would never admit of being brightened.

On the other hand, the fact that the fibre is found intact after the operations of dyeing, whilst it would be disorganized if its combination with the coloring matter were brought about by the union of atom to atom, in virtue of the force of attraction; and also the fact, that indigo unites with the fibre, while retaining all its properties, do not prove that there is no combination between the tinctorial matter and the fabric; the explanation of these apparently abnormal phenomena depends, in PERSOZ'S opinion, entirely on the point of view from which one regards them, and on the distinctions which are established in the phenomena of attraction.

In the existing state of knowledge, the inertia of matter is considered as a general property of bodies, and it is acknowledged, that if their particles are kept in equilibrium in relation to each other, it is by their being submitted to the influence of two opposing forces, which tend the one to draw them together, the other to separate them. The first, the only kind of action which requires attention at present, is designated by the name of *attraction*; but as it acts sometimes on masses which are placed at great distances from each other, at others on particles which are in immediate contact, it has, whether rightly or wrongly, been distinguished into *planetary* attraction and *molecular* attraction; further, as this last is manifested, either on particles of the same nature, which are thus attracted towards each other so as to form an aggregate of homogeneous particles, or on particles of a heterogeneous nature, to create a *whole* different and distinct from the composing atoms, the molecular attraction has been further divided into *cohesion*, or a force tending to unite molecules of the same nature, and *affinity*, or that force which tends to unite molecules of different nature, or to bring about what chemists term *combination.* These distinctions will sooner or later disappear, for they are less to be regarded as truths than as the necessary results of the wants of a particular period. What characterizes, in fact, the first phase of the development of a science, is always a tendency to differentiate and group the phenomena which it presents; but as the science becomes more advanced, there is soon produced a reaction, the contrary tendencies of which have no other end than the assimilation and binding together of all the elements of which it consists.

As it is attraction which animates the material particles, it must be recognised as the cause of the movement of matter, and accepted, without wishing to ascend higher, as an essential property of bodies, which can no more be explained than *extent* and *impenetrability.*

These preliminaries being laid down, and regarding as identical the phenomena of cohesion and affinity which appear to him the effects of one and the same cause, PERSOZ thinks it may be proved that the fixation of the colors on stuffs is only due to attraction. To arrive at this demonstration, he lays down, in the first place, some general considerations on the fixation of coloring matters; then passes in review the principal phenomena of attraction, with the double object of bringing out the differences which they may present, and discovering those which exhibit the greatest analogy with the fixation of this or that color.

The organic and the inorganic kingdoms, especially the former, furnish a great number of substances which possess the property of dyeing stuffs, either constituting colors by themselves, or entering as elements into coloring compounds of a more complicated nature; but, to receive an application, these substances, simple or complex, must unite, if not by themselves, at least by the intervention of a suitably selected body, two essential qualities: first, *that of being insoluble or nearly so;* second, *that of resisting as much as possible the destructive action of the air and the solar rays.* The first of these qualities is indispensable; for if it be wanting, there is *coloration* of the goods, but not *dyeing*, in the proper sense of the word: a simple washing with water suffices to discharge the color. The second is not essential in the same degree, since it is subordinate to the stability which is intended to be given to the colors applied to a fabric.

Indigotin, carthamin, curcumin, oxide of iron, oxide of chromium, sulphide of arsenic, sulphide of antimony, are dyeing substances by themselves. When one interrogates experiment as to the means of making them adhere to the goods, so strongly as to constitute one body with them, it is found to be necessary either to form these colors on the stuff itself, by putting in presence of the latter the elements of which they consist, and one of which at least must be soluble, or, if these tints are previously formed, to make them enter into a soluble combination with which one impregnates the fabric to set them afterwards at liberty, in such a manner that they may be in immediate contact with it at the moment when they pass from the soluble state in which they existed in their combination, to the state of insolubility which belongs to them in their isolation. It is thus that the blue color of indigo fixes itself on the goods only so far as they are saturated with reduced indigo, and afterwards exposed to the action of the air, which, by its oxygen, transforms the indigo-white into indigo-blue; that the rust color of sesquioxide of iron is stable only to that extent in which it is deposited on the fabric in the nascent state, either as protoxide, which, by oxidizing in the air, passes by degrees into the state of sesquioxide, or in the state of sesquioxide at first. The color of sesquioxide of chromium is fixed only in the same conditions. Again, to make the sulphides of antimony and arsenic adhere, it is sufficient to apply to the goods one of the saline and soluble combinations of these bodies, then to decompose it by an acid so as to set them at liberty. The fixation of carthamin takes place under circumstances nearly similar.

The greater part of coloring matters—nine-tenths at least—are not of a dyeing power by themselves, and only become so by entering into a combination which has for its object, not only to give them the first quality essential to every tint for being fixed, *insolubility*, but oftener also to make them contract a shade which they do not assume by themselves. The coloring matter of madder, for example, which is soluble in water, acquires the property of dyeing only in so far as it is combined with a body capable, in the first place, of forming with it an insoluble compound, as certain fatty substances, the oxides of aluminum, tin, iron, *et cetera*, and then making it contract the hue which one desires to obtain.

The different dye-woods do not dye better by themselves than madder: and they require, like it, to enter previously into a combination.

Chromic acid itself, rich as it is in color, becomes a dyeing substance only so far as it forms part of a saline combination, which should present, along with the shade desired, the greatest possible insolubility. Even the alumina, which serves for a base to all the organic colors, is not capable of fixing the chromic acid.

It is only in so far as they are formed on the stuffs themselves, that the dyeing compounds of this group become adherent to them. In any other case there is no dyeing, unless, as sometimes happens, the combination becomes by slow degrees insoluble, either by itself —*carthamin*—or by the intervention of a suitable agent—*catechu.* Experience proves, moreover, that of the two substances which usually concur or co-operate to the formation of the color, it is that which is insoluble which should be fixed first on the fabric, and with the same precautions as if one were dealing with one of the substances which are of a dyeing nature when used by themselves. The dyer deviates from this rule, only in so far as the elements of the lake, happening to be equally soluble, and endued moreover with an equal inclination for the fibre of the stuff, render it a matter of indifference whether the latter be first impregnated with the one or the other: thus the colored combination which is formed by nut-gall and a ferruginous preparation, is rendered adherent either by first depositing the iron compound on the fabric, and afterwards passing the latter into a decoction of nut-gall, or by commencing with impregnating the stuff with this infusion, to pass it afterwards into a ferruginous preparation.

This rapid glance at the formation and fixation of dyeing substances, will doubtless suffice to make it understood that the subject under consideration presents different orders of facts, which it is necessary not to confound. In the fixation of indigo, for example, there are, on the one hand, the formation of indigo-blue, and on the other, the adherence of the latter to the stuff. The first of these facts enters into the phenomena of oxidation that are best defined; the second into those of adherence or juxtaposition, which are confounded more or less with the facts pertaining to the aggregation of similar particles. In the fixation of the color of madder, and of all its congeners, there are in like manner two orders of facts: the one which relates to the most clearly understood chemical actions—namely, the union of this coloring matter with the oxide, which is called in to give it, besides the insolubility necessary to it, the desired shade; the other, which consists in the juxtaposition and adherence to the stuff, of the lakes which it produces. So, in the fixation of chromic acid, considered as a coloring matter, it is necessary to distinguish between the formation of the colored saline compound which one wishes to obtain, and its fixation, properly speaking, on the fabric. There are, therefore, in all the operations of dyeing and of the fixation of the colors, certain phenomena, which, inasmuch as they belong to the most common chemical reactions, cannot give rise to any discussion; let it now be considered whether it be not possible to dissipate likewise all uncertainty in what concerns the others.

Always when two bodies are brought into contact in suitable conditions to react upon one another, their molecules, by combining, or being in juxtaposition, form a compound which differs in its properties from those of the component substances, by so much the more as the physical properties of these last exhibit a greater difference from each other. Thus, in the oxides, as in the greater part of the metallic sulphides, the properties of the metals have almost completely disappeared, whilst in the combinations of the metals which present less dissimilitude among themselves, the properties of the compounds approximate more to those of the components. It is more especially in the saline combinations of a high order that the justness of this remark is evidenced.

In running over the scale of chemical affinities, from one of its extremities, where two bodies, endued with opposite properties, combine to form a whole, which, most generally, has no longer any apparent resemblance to its components, to the other end of the scale, at which bodies unite without their union giving rise to physical phenomena that are apparent, or that manifest any notable changes, one remarks that, in general, the compounds which differ most in volume from that of the mean of the components, are those in which the greatest differences are shown; and further, that the combinations which, in taking place, develop the most heat, are those in which the properties of the compounds exhibit the greatest divergence from those of the component materials.

Along with these phenomena, in which two simple or compound bodies are attracted to one another to form a new whole, having more or less resemblance to the components, there are others which, in appearance, seem to be different from the former, but which, in reality, belong to the same order, as the reader will be able to judge.

It is known that two very flat smooth plates laid one over the other, without the interposition of air, adhere together; and by an experiment of M. CLEMENT DESORMES, two plates of glass thus placed on each other were found to unite or solder together so strongly as to form as it were but one piece. It requires, therefore, only *juxtaposition* to determine a species of attraction; and hence it may be conceived that the molecules of a saline solution, whether of the same or of a different nature, but physically comparable both in regard to their dimensions and their geometrical form, may give rise to an aggregate, reproducing on a large scale the figure which they have in that state of extreme division in which they are not visible: it is seen also, that the particles of a salt held in solution pass to the solid state by assuming a definite form, which is the same whatever be the size of the crystals. In like manner, when, by a sharp stroke, one causes the disaggregation of a crystal of Iceland spar, it is found that the pieces into which it is divided are a faithful image of the mass. On calculating the volumes of the equivalents of the sulphates of zinc, magnesia, and iron, one finds that they are the same, and may be represented by 896 cubic centimetres; it is not surprising, therefore, that these salts crystallize together, and in every proportion; and as they affect the same crystalline form, and the dimensions of their molecules are the same, it hence results as a consequence that, in a given condition, they may concur in the formation of an aggregate which will contain without distinction predominant quantities of one or the other of these salts. The volume of one equivalent of octahedral alum is 3584 cubic centimetres; that of chrome alum, isomorphous with the former, is 3584 cubic centimetres; a crystal of ordinary alum may, therefore, be developed in a solution of chrome-alum, without changing its form, and reciprocally.

The difference which exists between these two orders of phenomena is, that in the latter the juxtaposition is immediate, so that particles of the same or a different nature, but identical in form and dimensions, being in contact, place themselves close to each other, whilst in the former this juxtaposition has not the same character, being subordinate to the changes which supervene in the dimensions of the particles of the heterogeneous bodies which are present. Whence it must be concluded, as regarding this latter order of facts, that to find the conditions in which two bodies combine, is to establish the condition in which their molecules are brought to the dimensions which render their juxtaposition possible, whether it be that one of them, by giving up the whole or part of the caloric which holds its particles at a distance, is brought to the dimensions of that in the presence of which it is, or, on the contrary, that by absorption of caloric, the particles of this body acquire the volume which they must occupy in the combination.

Lastly, there is a third order of phenomena which are more difficult to reconcile than the former two: those, namely, which are especially exhibited by porous bodies, or bodies reduced to powder.

The writings of Morozzo, Rouppe, Noorden, and especially those of Theodore de Saussure, have made known, with reference to this subject, facts of the greatest importance, by showing the property possessed by all porous bodies, and charcoal in particular, of absorbing gases—an absorption which depends:—

1st. *On the degree of heat at which it is conducted*, since the absorption is greater in proportion as the temperature is lower.

2nd. *On their pressure*, the absorption being greater in proportion as the pressure is higher.

3rd. *On the nature of the gas*, since equal volumes of a charcoal of the same nature absorb the following proportions of the different gases enumerated: namely,

90	times their	volume of	ammoniacal gas.
85	,,	,,	hydrochloric.
65	,,	,,	sulphurous acid.
55	,,	,,	sulphide of hydrogen.
40	,,	,,	nitrous oxide.
35	,,	,,	carbonic acid.
35	,,	,,	bicarbide of hydrogen.
9·42	,,	,,	carbonic oxide.
9·25	,,	,,	oxygen.
7·5	,,	,,	nitrogen.
1·75	,,	,,	hydrogen.

4th. *On the nature of the absorbing bodies*, since, as De Saussure has remarked, meerschaum absorbs more nitrogen than hydrogen, and, on the contrary, the different woods condense more hydrogen than nitrogen; and of all the bodies on which this chemist operated, silk, wool, flax, tin, the wood of hazel, mulberry and willow, pyrophorus, metallic powders, plasters, spongy carbonate of lime, Vauvert quartz, hydrophany, asbestos, brittle schist, meerschaum, and the charcoal of boxwood—of all these substances the last exhibited the greatest absorbing power.

5th. *On the number of the pores*, for if two equal weights of the same charcoal, one of which has been finely pulverized, are put in contact with the same gas, the charcoal not pulverized absorbs 7·25 times its volume, and the other only 4·25.

6th. *On the diameter of the pores*, for, according to De Saussure, the charcoal of cork, the density of which is 0·1, does not sensibly absorb air, while that of willow, having a gravity 0·4, absorbs four and a half times its volume, and that of wood with a density of 0·6, seven and a half times its volume.

7th. Lastly, *on the emptiness or vacuity of the pores*, which makes the absorption the greater in proportion as it is more complete.

The gases fixed in this manner are absorbed in their entirety, without undergoing decomposition; for the slightest elevation of temperature, or a diminution of pressure, is sufficient to set them at liberty, retaining all their properties. Oxygen and nitrous oxide are the only gases which, when absorbed by charcoal, are no longer given out in a complete form, seeing that in these circumstances they enter into combinations with that body.

The action of porous bodies is so powerful, that Dobereiner, Dulong, and Thenard, and many others after them, have turned this property to account to realise chemical combinations in conditions of temperature in which it was far from being supposed that such were possible. How does it happen that in these experiments the effect of a porous body is equal in power to that which would only be obtained by a pressure of several atmospheres, or by a considerable depression of temperature, if the liquefaction of the gases were attempted directly?

The effect which solid and porous bodies produce on the gases is equally realised by liquids which, as is well known, dissolve them. It has even been observed in connection with this subject, that the absorption of gases by porous bodies is in proportion to their solubility in water, since, as far as can be ascertained, those which dissolve most easily in water are also those which are absorbed in the greatest quantity.

With this same class of phenomena are connected another series of facts not less surprising, but less clearly established: animal charcoal, brought into contact with solutions of coloring matter, renders them colorless, and this property is common to it with many other bodies, such as metallic oxides and basic salts. But the question arises, are the reactions of these different bodies on the colored solutions due to the same cause? Does the charcoal act in the same conditions as the metallic oxides and the basic salts? Evidently not; for it is because these last intervene as elements generating the salts, that they fix quantities of coloring matters proportional to their respective equivalents; and besides, the coloring matter is only separated from them by the intervention of a body which performs the same chemical part, but with a greater energy, whilst, unless by recognising in charcoal a property which has been denied of it hitherto, that of generating salts, it must be admitted that its action is quite special, quite distinct, or that that on which its decoloring power depends is not pure charcoal, but organic or inorganic matters contained in it, capable of attracting colors.

The effects of porous bodies, and especially of charcoal, do not end here; for it has been proved that the power of the latter is sufficient to overcome even pretty strong chemical affinities. According to the experiments of Mr. Graham, it possesses the property of taking oxides, not from neutral salts, on which it has no action, but from many basic salts and solutions of metallic oxides in alkalies; and in these circumstances the intimacy of the contact is such that lead and silver salts especially are reduced, and the metals set at liberty.

M. Chevalier not only coincides with Mr. Graham as to these effects of charcoal, but even goes still further, and affirms that the action of this body extends actually to neutral lead salts, for he alleges having taken by means of charcoal all the oxide of lead from a given weight of nitrate of lead previously dissolved in water. The contradictory nature of the results obtained in reference to this point by Messrs. Graham and Chevalier requires a new examination; but, as the latter has not shown by direct experiments how far the charcoal which he employed was pure, and free from all organic or inorganic matter, the action which he attributes to this body on nitrate of lead may be regarded as doubtful, till proof to the contrary is adduced.

It results from all these facts: 1st, That gases may be absorbed by porous bodies, as they are by water, in virtue of an action quite special, the cause of which it is not necessary here to investigate; 2nd, that charcoal is capable of decolorizing dye-baths, and taking oxides from saline solutions. But in connection with this subject, new researches are necessary to establish this property; for if the experiments of DE SAUSSURE and those of CHEVREUL on the different textile fibres, put it beyond doubt that gases are condensed by the fibre in the same manner as they are by charcoal, it is far from being established that charcoal comports itself like the fibre in presence of coloring matters; otherwise, like charcoal, the fibre would decolorize a bath of cochineal or madder, and the contrary is proved to be the case; it is even known that when a stuff is well scoured of foreign matters, it always fails to attract a particle of coloring matter, whilst it uniformly takes the dye in greater or less perfection if metallic oxides or spots of grease exist at its surface.

Having now enumerated the different cases of combination, all of which reduce themselves, either to a juxtaposition preceded by a change of the dimensions of a compound, or to a direct juxtaposition, or lastly, to an absorption of the liquid and gaseous bodies by the solid and porous bodies, it remains to examine to which of these phenomena the fixation of colors on stuffs appears to belong. It has been already remarked, that the formation of a color, which must be carefully distinguished from its combination with the fabric, enters decidedly into the first class of phenomena, which have been just pointed out; such, for example, is the formation of indigo-blue, that of madder-lake, and all the lakes of this description, that of chromate of lead, *et cetera*. But, this formation being effected, how do all these colored bodies remain united to the fibre? Is it in virtue of an *immediate juxtaposition*, or from the capillary force of the pores of the different kinds of fibres, which may act here in the manner of porous bodies—of charcoal, for example? In PERSOZ's opinion, this adherence of the colors is due to an immediate juxtaposition, the coloring matter being deposited, not in the pores of the staples of cotton, wool, and silk, but at their surface, which, as may be observed by the microscope, is composed of facets somewhat similar, in the case of wool, to the scales of fish. Indeed, if a piece of calico be dipped several times in a vat of deoxidized indigo, with the precaution of exposing this fabric to the air after each immersion, the process will result in giving it at last a most intense blue; now, if the adherence took place in virtue of the capillary force of the textile fibre of the cotton, a period would arrive when the pores, being filled, would produce no more action on the dye-bath, in which, consequently, the fibre would be no longer susceptible of being charged with coloring matter; and yet experience proves that one can always make new coatings adhere to it, the want of fixation of which only proceeds from the circumstance that they are not in immediate contact with the fibre. This phenomenon is especially remarkable in the coloration of calico by oxide of iron; for if, by successive immersions of the stuff in a ferruginous preparation, one accumulates upon it very large and very varied quantities of the iron oxide, the molecules of this last are so brought into juxtaposition as to form a concretion, just as the molecules of certain salts held in solution in water deposit themselves in successive layers, to give rise to those incrustations so well known in certain localities; and nothing can prove more clearly that the sesquioxide of iron is only a deposit at the surface of the fabric, than the facility with which one can always remove from any part whatever of one of its colored faces the whole or part of the oxide, so as to cause the white of the fibre to reappear. But, if the colors were lodged in the vessels or pores of the stuff, how could they be detached from it by an operation in some sort mechanical? How should J. M. HAUSSMANN have succeeded, as he states in his important memoir on indigo, in decolorizing completely a piece of calico dyed with much care in indigo-blue, by leaving it to itself in the small stream which passes through his establishment. In tracing up this decoloration to its cause, this manufacturer has shown that it must be attributed to the mechanical action of the particles of silicious sand which the stream carries along, and which, by rubbing against the surface of the stuff, gradually detached from it all its colored particles. On the other hand, if the adherence of the colors is the result of a capillary action in relation with the pores, how does it happen that when the pores are lined with a colored lake, a cloth saturated with red will receive the impression of a blue color which produces the effect of black upon it, or of a yellow color which produces orange; or how does a cloth charged with blue color receive the application of a red color which produces brown, or of a yellow color which produces green? It is evident that these different phenomena can be explained only by a juxtaposition of the dyeing substances to the surface of the textile fibre. Lastly, if this adherence depended on the pores, all insoluble substances ought to admit of being lodged in these pores—the sulphate of baryta as well as the sulphate of lead—the carbonate of baryta as well as the oxide of lead—the oxide of zinc as well as the oxides of aluminum and of tin. Now, does experience prove that it is so? Does it not show, on the contrary, that some of these substances, such as the sulphate and carbonate of baryta, the sulphate and carbonate of lime, never adhere to the fibre, whatever conditions they are placed in, whilst others combine with it with the greatest readiness? In PERSOZ's view of the subject, these differences of results have nothing extraordinary, since, as he demonstrates in his introduction to the study of chemistry, the dimensions of the elementary atoms of bodies not being the same, their volumes are represented by the terms of two regular geometrical progressions, and hence it is natural, that not presenting all the faces similar to those of the fibre, they have not all an equal aptitude to adhere to it. It is, besides, a fact which seems to justify the influence of the dimension and form of a molecule in the fixation of coloring matters, that among the metallic oxides, those which combine with most energy with fabrics, and in conditions the least different, are precisely the hydrates of the three isomorphous oxides subjoined :—

	Cubic centimetres.
Sesquioxide of iron, the volume of the equivalent of which is	168
Sesquioxide of aluminum,	168
Sesquioxide of chromium,	168

The Editor has had occasion more than once to remark, that the compounds deposited on wool and on cotton become adherent to it in different conditions: thus, it may be advanced as a general rule that a color adheres to cotton, only in so far as it presents an alkaline reaction with it, or that the fabric impregnated with it is dipped in an alkaline bath; now, this alkaline influence is precisely that under which the textile fibre contracts. Wool, on the contrary, is strongly contracted by acids, and often it is only under their influence that one succeeds in fixing colors upon it; would it be surprising, therefore, that in the case of juxtaposition between the colors and the fibre, changes in the dimensions of the latter should contribute to the very act of the fixation?

Lastly, it may be safely inferred that the fibres of wool, silk, and cotton, which admit of receiving the same colors without reflecting the same shades, owe this property to their configuration.

Fixation of Colors on Pyroxilized Tissues.—From the preceding remarks, it will be generally admitted that Persoz has fully settled the question in favor of the chemical theory of the fixation of colors; and many additional facts might be urged in support of the same view. Even organized tissues, both animal and vegetal, can and do unite, not only chemically, but proportionally or atomically, with other substances, without their organization being destroyed. A notable example of this is found in pyroxilin or gun-cotton, which is prepared by immersing cotton wool in a mixture of nitric and sulphuric acids; in the action of caustic soda on cotton at a low temperature; in the combination of chlorine with woollen, and other analogous cases.

In the *Comptes Rendus* for April, 1856, appears a series of interesting papers by F. Kuhlmann, relating the results of certain experiments which he made to discover whether cotton, modified by combination with the elements of nitric acid, or by transformation into pyroxilin, would acquire a peculiar disposition for absorbing coloring matters. The idea which seems to have actuated him in this inquiry, was the effect produced by the so-called animalization of vegetal tissues with cow-dung in Turkey-red dyeing—an effect which was formerly attributed to the assimilation of the cotton to animal or nitrogenized materials, such as silk and wool, which exhibit the greatest aptitude for the reception of colors. Since it has been found that several saline substances, particularly silicate of soda, may be successfully substituted for the dung as a means of fixing the mordants, the theory which ascribed its effect to the animalization of the vegetal tissues has been abandoned, but a new light dawns on the subject from the following experiments of Kuhlmann.

He carefully prepared a quantity of pyroxilin with cotton and linen tissues, and also with cotton wool, operating by Meynier's process with a mixture of monohydrated nitric acid and concentrated sulphuric acid. The pyroxilin was washed several times with a large quantity of water, soaked for some time in a solution of crystallized carbonate of soda, and washed again. The pyroxilized tissues were prepared for dyeing by the following treatment:—They were soaked for twenty-four hours in cold water, pressed and rinsed, then soaked in boiling water, and after a fresh washing they were half-dried and calendered for printing.

Various mordants were printed simultaneously upon pyroxilized linen and cotton tissues, and upon portions of the same in their natural state, the latter having been completely freed from foreign matters by boiling for three hours in a weak solution of carbonate of soda, then washed and treated with a bath slightly acidulated with sulphuric acid, and after being washed again and half-dried, calendered to prepare them for printing.

The nitrogenized and non-nitrogenized tissues were printed at the same time with the following mordants:

Black,	Crude acetate of iron of 10° Twaddell. Thickened with starch.
Puce,	2 parts of crude acetate of iron of 15°. 1 part of crude acetate of alumina of 12°. Thickened with starch.
Red,	Crude acetate of alumina of 12°. Thickened with soluble starch.
Violet,	Crude acetate of iron of 2°. Thickened with soluble starch.
Lilac,	Crude acetate of iron of 1°. Thickened with soluble starch.
Brown,	Decoction of catechu with acetic acid. A little nitrate of copper.

After impression, the tissues were suspended for six days in the cold, and one day in the hot oxidizing chamber. They were freed from gum in a bath of cow-dung and chalk of 158° for ten minutes, well cleaned, treated a second time in the same bath at the same temperature, cleaned and rinsed. The dyeing was effected with garancin in a bath of river-water slightly acidulated, commencing with a temperature of 95°, and rising gradually in three hours to 185°; lastly, the tissues were pressed, rinsed, and dried. The dyed samples were halved, and one-half of each bleached with chloroxide of calcium.

These operations proved the following facts:—All the nitrogenized tissues remained excessively pale compared with the non-nitrogenized ones, notwithstanding the superabundance of the coloring matter. The nitrogenized tissue, although it rejects the mordants, appears to possess the power of combining, without their aid, with a portion of the coloring matter of madder, to judge from the yellowish tint which remains even after the treatment with bleaching powder.

To ascertain whether these results were due to exceptional causes, especially to a portion of acid which might have escaped the washings, Kuhlmann repeated his experiments, soaking the nitrogenized tissues for twenty-four hours in a weak tepid bath of crystallized carbonate of soda, rinsing them, and washing them repeatedly. They were then calendered, moistened, and printed after drying. After immersion in the mordants, they were suspended in the fixing chamber for eight days. They were freed from gum, and dried in the same way as in the preceding experiment, when exactly the same results were obtained.

Other pieces of cotton, and one of linen, were heated with a hot-bath of crude acetate of iron, and then passed into a bath of nut-galls. The nitrogenized tissues acquired a very pale tint compared with those in their natural state.

Dyeing with Prussian-blue was then tried upon cotton wool. As in the black-dyeing with gall-nuts, the pyroxilized cotton only acquired a very pale tint compared with that in the natural state. The same results were obtained in a series of experiments with cotton wool, in which Brazil-wood was substituted for garancin.

M. Béchamp's recent experiments having shown the possibility of reducing pyroxilized cotton to its original state, Kuhlmann wished to ascertain whether in this case it also regained its capacity for dyeing; he found that pyroxilin, treated by Béchamp's process, recovered its property of receiving colors.

Happening to have retained a considerable quantity of pyroxilized cotton tissues, which were rolled up tightly, and kept in a wide-mouthed bottle closed with a cork, he observed in about two months that the bottle was filled with nitrous vapors, and that the cork, which was corroded by nitric acid, had been raised to give passage to the reddish vapors. He was unable to ascertain the cause of this spontaneous decomposition, for some pyroxilized cotton which had been dyed and preserved for the same period had undergone no alteration. He washed the decomposed pyroxilin, but its texture was greatly changed, and tore with a slight touch, and its inflammability was considerably diminished.

The results of its analysis, as confirmed by M. Wurtz, were as follow:—The substance was dried *in vacuo* at 212° and 230° Fahr.

Carbon,	31·25
Hydrogen,	4·08
Nitrogen,	7·88

The analyses of gun-cotton give—

	Demonte and Menard.	Bechamp.	
Carbon,	28·5	28·5	27·9
Hydrogen,	3·5	3·5	3·5
Nitrogen,	11·6	10·5	11·1

The comparison of these results shows that pyroxilized cotton, after this spontaneous decomposition, contains two-thirds less nitric acid than unaltered gun-cotton.

This partially denitrified pyroxilin was dyed with garancin and Brazil-wood after mordanting with acetate of alumina, when Kuhlmann was astonished to find, not only that it no longer rejected the coloring matter like pyroxilized cotton, but that it furnished infinitely stronger and brighter colors than non-nitrogenized cotton treated in the same way. Thus, with Brazil-wood and a mordant of acetate of alumina, a tint approaching scarlet was obtained, and this induced him at once to attempt the production of a nitrated cotton with the same power of fixing colors possessed by that which he had obtained by accident. After ascertaining unmistakably that the nitrous elements retained in this were in chemical combination with the cellulose, he soon perceived that these elements had not entered into such a stable state of combination, in the presence of salts of protoxide of iron, as that in which they exist in pyroxilin.

Pyroxilin, both in its decomposed and ordinary states, was exposed to a gentle heat in a bath of protosulphate of iron. In a very short time the altered pyroxilin acquired a chamois-yellow color, whilst the undecomposed pyroxilin took up much less oxide of iron than ordinary cotton under the same circumstances. The same differences of color were reproduced when the oxide of iron was converted into Prussian-blue, by a slightly acidulated bath of ferrocyanide of potassium. He thus found that pyroxilin, by losing a portion of its nitrous elements, not only loses its resistance to the absorption of mordants and colors, but actually becomes far more capable of becoming charged with these bodies than non-nitrogenized cotton. This induced him to commence a fresh series of experiments with cotton stuffs, which, before receiving the mordant, had been in contact for a longer or shorter time either with nitric acid of various degrees of concentration, or with variable mixtures of nitric and sulphuric acids. The results were very remarkable. With Brazil-wood, acetate of alumina gave violet-red tints upon non-nitrogenized cotton; immersion for twenty minutes in nitric acid of specific gravity 1·30, followed by washing with a large quantity of water, and immersion in a weak solution of carbonate of soda before the application of the mordant, gave a far deeper and less violet-red color than that taken by the cotton which was not prepared with acid. This result was confirmed by several successive trials. A very sensible effect was produced, even by the immersion of the cotton for half an hour, in the same acid diluted with double its volume of water; and in this case the tenacity of the cotton was not perceptibly altered.

In the following comparative experiments—

No. 1 was cotton without any acid preparation;
No. 2, cotton kept for five minutes in a mixture of two volumes of nitric acid of specific gravity 1·30, and one volume of sulphuric acid of specific gravity 1·85;
No. 3, cotton kept for two minutes in a mixture of equal volumes of nitric acid and of sulphuric acid;
No. 4, cotton kept for twenty minutes in a mixture of one volume of nitric acid and two volumes of sulphuric acid;
No. 5, cotton kept for twenty minutes in a mixture of one volume of nitric acid, two volumes of sulphuric acid, and half a volume of water.

After the acid baths, the stuffs were washed with a large quantity of water, passed into a bath of carbonate of soda, washed again, and finally passed into a mordant of acetate of alumina. The dyeing was effected with a decoction of Brazil-wood.

No. 1 took a pale violet-red color;
No. 2, a less violet-red tint, but still rather pale;
No. 3, a deeper and brighter color;
No. 4, a much deeper poppy-red color, very like that obtained with the decomposed pyroxilin;
No. 5, a deep red color of extraordinary richness. Under the same circumstances, but with a stronger dye-bath, a splendid red color was produced of such depth that it appeared brown. The same results were obtained in several repetitions of the experiments.

From this it evidently follows, that a mixture of sulphuric and nitric acids furnishes colors most approaching scarlet, and that the best results are obtained with a bath consisting of one volume of nitric acid of specific gravity 1·30, two volumes of sulphuric acid of specific gravity 1·85, and half a volume of water.

He also made some comparative trials of dyeing with cochineal and archil upon cotton. The mordant was acetate of alumina. Immersion of the cotton for twenty minutes in a bath of pure nitric acid, or a mixture of two volumes of nitric acid and one volume of sulphuric acid, gave with cochineal a pale red tint, very like that produced without an acid bath. The same immersion in a bath of one volume of nitric and one volume of sulphuric acid gave a much deeper color. A mixture of one volume of nitric and two of sulphuric acid gave a color of at least double the intensity of the preceding.

With the last acid mixture, also, a pretty strong color was obtained upon cotton with archil.

With garancin, a bath of nitric acid alone gave a yellower, but not a deeper tint than upon cotton which had not been nitrogenized. Two volumes of nitric and one volume of sulphuric acid gave a similar tint, but deeper than the preceding. Equal volumes of the acids gave a very fine brownish-red color, like the Turkey-red before the *avivage*, or clearing. One volume of nitric and two volumes of sulphuric acid gave the same intensity of color, but a shade more approaching orange. Lastly, twenty minutes' contact of the cotton with a mixture of one volume of nitric acid, two volumes of sulphuric acid, and half a volume of water, gave a very bright red color, of much greater intensity than the preceding.

All these experiments were repeated with wool, silk, feathers, and hair, previously submitted to the same treatment as the cotton, with remarkable results as regards the intensity and richness of the colors. Even with nitric acid diluted with five times its volume of water, the effects are very distinct.

As in treatment with concentrated acids, the threads or tissues, especially those of cotton or linen, are considerably altered, so that the preceding results cannot be generally applied in dyeing, KUHLMANN attempted the fixation upon these tissues of different nitrogenized matters produced by the action of concentrated nitric acid upon certain organic bodies. Picric acid, which does not attach itself to cotton with a mordant of alumina, gives very strong tints when the cotton has been nitrated. In this case the acid acts as a coloring matter, but it acts also as a mordant, especially in producing compound colors, either by using baths of picric acid after the application of the ordinary mordants, or by mixing the acid in variable quantities with the color in the dye-bath. The colors thus produced are very bright, but they are more applicable to dyeing upon wool and silk, as upon cotton the picric acid reacts in time upon the coloring matter, usually causing it to become yellow.

From these experiments, KUHLMANN concludes that the chemical composition of the bodies to be dyed has the greatest influence upon the fixation of color, that dyeing is a true chemical combination, and that the effects due to capillarity, and the peculiar structure of the material, are but secondary.

PRINCIPLES OF THE ACTION OF THE MOST IMPORTANT MORDANTS.—Hitherto, the term *mordant* has been applied to every substance which possesses the twofold property of uniting, on the one hand, with the goods, and on the other with the coloring matters. From this, it might appear that the mordants possess properties quite peculiar, whilst in reality it is not so. Placing oneself in the point of view which accords with the theory advanced by PERSOZ, one sees in these bodies only the elements, the constituent principles, of a saline compound which forms on the fabric itself to become adherent to it.

From the fact that the colorable and colored principles all combine with the metallic oxides to form insoluble compounds, it would seem also that these last should all be capable of fulfilling the part of mordants, and, consequently, of becoming the base of the colored lakes formed on the stuff. It is not so, however; the number of bodies which possess this property is very limited. They are, among the compounds of the inorganic kingdom, the oxides of aluminum, iron, chromium, and tin; among the products of the organic kingdom, the modified fatty bodies. The Editor has already pointed out a resemblance of the oxides of aluminum, iron, and chromium among themselves, observing that the volume of their equivalents is the same; considered under another relation, these three compounds are, of all the metallic oxides, those which exhibit in the highest degree the property of passing from a state in which they possess their full aptitude for combining, to an isomeric state in which they become indifferent in the presence of the most energetic agents.

For a body to be capable of performing the part of a mordant, it is necessary, in accordance with the views already stated, that the dimensions of its molecules be in a simple ratio to those of the surface of the fibre, and that, being fixed on the fabric, it give rise to a colored compound, the faces of which, being also in a simple relation with those of the fibre, cause its adherence.

All the mordants do not in the same manner render the colors adherent to the stuffs; some cause them to undergo only slight changes of shade, depending on the acid or basic character which the mordant performs, and especially on the dimensions of the colored molecule which is formed. Thus, let hydrate of lead, on the one hand, be deposited on a stuff, and on the other, hydrate of alumina, both colorless, but possessed of different properties, and let this stuff be passed into a bath of cochineal; the aluminous mordant will be dyed red, and the lead mordant a deep black. The same will be the case, and for the same reason, with hydrate of tin and hydrate of alumina, which, if fixed on a stuff and dyed in a madder bath, will give—the latter, a red inclining to rose-violet, the former, a red inclining to orange. The others, particularly the oxide of iron, cause the colorable or colored principle to previously undergo an alteration; for, if the iron oxide combined purely and simply with the coloring matter of the madder, for example, which in its state of isolation is of a clear brown or orange-yellow, one should obtain lakes of a clearer color than that which is peculiar to this oxide, whilst lakes are produced of which the shade varies from the most intense black to the most delicate lilac, according to the proportion of oxide on the stuff.

The nature of the principal mordants being known, the first point to be investigated is this—whether it be a matter of indifference to employ one saline combination rather than another, to render their base adherent to the goods? There are, in this question, two points to be considered: the first is one which the manufacturer should never lose sight of in the operations by which he applies a mordant on the goods, namely, the chemical part which this mordant, once fixed, ought to fulfil in presence of the coloring matter. Suppose, for example, that instead of having set at liberty on the goods hydrated alumina in that state in which it has all its chemical properties, it has, in point of fact, been deposited thereon in that state in which it loses momentarily all its aptitude for combining—the operation will be a failure, and goods thus mordanted will not dye. The second point is this, namely, that the brightness and intensity of the color which is obtained from a mordant depend on the manner in which this mordant is set at liberty, and passes into the insoluble state on the fibre, to be brought into immediate contact with it. Thus, let hydrate of alumina be prepared with every precaution, let one part of it be slowly dried, and another quickly, and there will be obtained, in the first case, a coherent mass of a horny aspect, in the second, a dull and opaque mass; and these two pieces, immersed in a solution of coloring matter of pure madder, will be dyed, the one of a red almost brown, the other, a dull and pale red. It is important, therefore, to seek, among saline combinations, that which yields most easily to the goods the base which it contains, and which is required to perform the part of a mordant, by preserving to this base all its chemical power, and the physical state most favorable to the reflection of the luminous rays.

ALUMINOUS MORDANTS.—The aluminous compounds which are used to deposit on stuffs the oxide of aluminum in the state in which it acts as a mordant, by attracting to it and fixing the coloring matter of a dye-bath, are of two kinds. In some, the alumina is in the state of a base; in others, it performs the part of an acid.

1. *In the basic state*, there are as many aluminous salts as acids, but all of them cannot be employed as mordants, those which are insoluble are taken off, by the slightest washing, from the stuff on which they are applied; such are the tri-basic sulphate, the phosphate, the phosphite, the arseniate, the borate of alumina, *et cetera.* Those which are soluble behave in three different manners: some are *basic*, or capable of becoming so by giving up a part of their acid, and therefore require to be only deposited on a fabric to yield to the fibre, either in the cold or with the aid of a temperature more or less elevated, all or part of the alumina which they contain; such are the pure or impure acetate of alumina, cubic alum, oxalate of alumina, the butyrate and the formiate. Others, either neutral or containing an excess of acid, are divided into two groups: 1st, the salts of alumina in which the oxide is not masked, and which, consequently, may always become mordants or yield their oxide to the goods when their acid is saturated with no base, or when, by the aid of another salt, by double decomposition, the formation of a new aluminous salt, insoluble and adherent to the stuff, is determined; to this category belong the sulphate, the seleniate, the chlorate, the bromate, the iodate, the bi-phosphate, the bi-arseniate, the nitrate, the chromate, the chloride, the bromide, the iodide, and octahedral alum; 2nd, the salts of alumina of which the base is masked, and which, saturated by an oxide, or mixed with another salt, would never furnish to the fabric an aluminous compound, insoluble, adherent, and capable of attracting the coloring matter. It is in this group that the tartrate, the citrate, and the malate of alumina range themselves. Thus, with the exception of these last three, it may be said that all the compounds of alumina can serve for mordants; with this difference, nevertheless, that some require only to be deposited on the stuff, at a temperature more or less elevated, to fix their base upon it, while others would remain upon it indefinitely without giving up alumina to the fabric, if by the intervention of something the base did not become free and insoluble. This will be better understood by repeating the following experiments of PERSOZ. After previously scouring with an acid from all foreign matters, the samples of calico A, B, C, D, E, he impregnated—

Sample A with a solution of acetate of alumina at 6° Twaddell;
Sample B with a solution of nitrate of alumina in the preceding liquor, and marking 12° Twaddell;
Sample C with a solution of nitrate of alumina at 6° Twaddell;
Sample D with a solution of *alum* in an acetate of alumina at 3°, and marking 9° Twaddell;
Sample E with a solution of alum marking 9° Twaddell;

and these samples, dried at the same temperature, in the same conditions, then rinsed several times in distilled water, lastly dyed in a madder bath, were found as follows:—

Sample A, charged with coloring matter of an intensity proportional to the quantity of oxide yielded to the fabric by the acetate.

Sample B—though impregnated with a preparation containing much more alumina—was dyed a much weaker shade, showing the influence of the nitrate which always renders the decomposition of the acetate a little more difficult.

Sample C, always colorless when the nitrate of alumina employed contained one equivalent of base for three equivalents of acid, and the cloth on which it was applied was entirely freed from the calcareous substances with which it is sometimes charged on coming from the operations of bleaching, which are always finished with washings in water.

Sample D, of a shade less intense, by half, than that of sample A, so that the alum associated with the acetate of alumina was a pure loss in the process.

Sample E, colorless like sample C, and in the same conditions.

When other samples, A′, B′, C′, D′, E′, were impregnated with the same solutions, but after being dried were passed into menstrua containing either bicarbonate of potassa or soda, or the neutral arseniate of potassa and a little chalk, or any other saturating body incapable by its nature of redissolving the aluminous compound which is formed; and when, as in the preceding case, all the samples had been washed and passed into a madder bath, the following was the state in which they presented themselves :—

Sample A′ had a shade of a much higher tone than sample A, the intervention of the basic compound having completed the precipitation of the alum on the goods.

Sample B′ was of a shade double the intensity of that of sample B, the alumina of the nitrate, precipitated by the intervention of the *saturating bath*, being added to that of the acetate.

Sample C′ of the same shade and tone as sample A′, for the reasons which have just been explained in speaking of sample B′, while C was colorless or very slightly tinged.

Sample D′ of a deeper dye than D, intermediate between those of A′ and B′, as being the product of the alumina of the acetate, to which was added the alumina of the alum precipitated by its being passed into the saturating bath.

Sample E′, instead of being colorless like sample E, had a tint, the intensity of which was proportional to the alumina of the alum which was fixed, that is to say, about half less intense than that of samples A and A′.

The chloride of aluminum gives the same results as the nitrate of alumina; nevertheless, as it decomposes by heat into hydrochloric acid and alumina, it gives up a part of its base to the goods when dried rather briskly, and may thus serve directly for a mordant; but this decomposition, which takes place without much danger on silk, cannot be effected on the ligneous fibre of cotton, flax, and hemp, without damaging it more or less.

The oxalate of alumina presents a peculiarity which it is the more important to point out, as it must be taken into consideration in a great variety of circumstances. At the moment of its formation, it is deprived of the property of yielding its base to the goods to such a degree, that oxalic acid is employed to remove the alumina from stuffs on which it is desired to produce a white figure; but by the prolonged contact, or instantaneously when the stuff is submitted to the action of steam—since every effect produced by time is always realized more rapidly by the intervention of heat—the oxalate of alumina undergoes a transformation, and, giving up a part of its base to the goods, becomes in this way a mordant.

Alum is, of all ingredients, the most generally employed as a mordant, and that which has been longest in use. It is impossible to go back to the period when it was introduced into dyeing; all that is known on this subject is, that in Hindostan it has been used from time beyond memory, and that in Europe, in the fourteenth century, the mode of its preparation was given by CESALPIN; but how does it happen that this salt, which cannot by itself yield its base to the goods, should have been the first of all the preparations employed? This will be understood when one considers that several kinds of alums exist—octahedral alum, the solution of which is not made turbid by heat; and cubic alum, more or less saturated, the solution of which is on the contrary rendered turbid by this physical agent, which then precipitates on the goods sulphate of alumina; and that the ancients knew only natural alum, which always contains an excess of base, but in variable proportions. Moreover, experience taught them to effect the saturation of alum and to render it basic, since they recommend, in all their works, the addition of a certain quantity of *natron* or of *potassa* to this body when one desires to use it for mordanting goods. It is even supposed that they then associated with their saturated mordants vinegar from rice or palm—in which there is nothing improbable; for, by making use of the carbonates of potassa and soda, they must, considering the state of their chemical knowledge, have sometimes precipitated a part of the base of the alum, and to remedy this accident and redissolve this base, they had no other acid than the acetic. At a later period, the acetate of lead was introduced in the preparation of mordants of alumina, but no proof exists that it was used by the Indians; there is every reason, on the contrary, to believe that it was in Europe that this salt was first turned to account, without its being possible, however, to particularise either by whom, or at what period—doubtless because the person who first applied it was too much interested to divulge a secret to which he was indebted for results so uniform. It is well known with how much mystery manufacturers were accustomed to invest their operations at a certain period.

To the acetate of lead there were added, as old recipes prove, several substances, such as acetate of copper, chloride of sodium, arsenious acid, orpiment, realgar, chalk, *et cetera*. Some of these substances are scarcely employed at the present day; but it must be confessed that at a period when chemistry was yet little advanced, they must have had their utility, some to prevent the fixation of the iron, the presence of which in the alum might injure the purity of the red, others to preserve the color in that hygroscopic state which the printing requires, or to contribute to give to the mordant, during its evaporation, that translucid and horny appearance which is the great object to be aimed at.

So far as is known at present, the octahedral alum has always the property of yielding to the stuff on which it is applied, all or part of the alumina which it contains, when it has been previously saturated, either with the acetates of lead, lime, baryta, and strontia, which by double decomposition give rise to sulphates more or less insoluble, and to a proportional quantity of acetate; or with the acetates of potassa, soda, lithia, ammonia, and magnesia, which do not produce any turbidity in the solution of alum; or with the carbonates of the last-mentioned bases, employing the first three in such proportions that the alum passes to the cubic state without precipitation of the alumina, and the last two, which are insoluble, in any proportions.

As regards the part performed by the alkaline carbonates with which the alum is saturated, it is very simple, since these salts have the effect of forming cubic alum, which gives by heat ordinary alum and basic sulphate, but in a proportion infinitely less than when one makes use of acetate, for scarcely a third of the saturating effect is obtained from the carbonates as from the acetates; and, after reaching a certain point, no more carbonates of potassa or soda can be added to a solution of alum without its precipitating. Nevertheless, if the saturation of the alum cannot be completely effected so long as this body is free, nothing prevents its accomplishment when it is deposited on the fabric. Indeed, let concentrated solutions of alum, saturated with carbonate of potassa or soda, be printed on calico, and after thoroughly drying the stuff to precipitate the alum, let it be passed, cold, into a bath containing bicarbonate of potassa or soda, or, better still, holding in suspension the arseniate of lime and potassa—it will in that case be perfectly mordanted, and will dye as well as that on which the acetate has been deposited.

The use which has been so long made of chalk, at least by the French and other continental dyers, to saturate the alum which enters into the preparation of Turkey-red, proves the saturating effect of this body; it even appears from the writings of J. M. HAUSSMANN, that alum can be charged with one-eighth of its weight of chalk, and lose the property of becoming turbid, which must be attributed, doubtless, to a particular combination which is effected between the lime and the alumina, which have a great affinity for one another.

Having thus pointed out the part performed by the substances which unite in the formation of aluminous mordants, the composition of the principal mordants in which alumina performs the function of a base will now be indicated, and at the same time the precautions to be taken in their preparation. In the first place, the composition of two old mordants of this nature may be given as a subject of comparison:—

OLD MORDANTS.

Red Mordant—from 1760 *to* 1800.

In twenty-two gallons of water were dissolved—

55·5	pounds	alum, to which were added:
5·5	"	arsenious acid.
5·5	"	litharge.
14·0	"	acetate of lead.
1·54	"	sulphide of antimony.
1·54	"	chloride of mercury.
3·3	"	carbonate of soda.

Another Mordant—from 1800 *to* 1824.

In twenty-two gallons of water were dissolved—

49·5	pounds	alum, and to this solution were added:
5·0	"	acetate of copper, previously dissolved in one quart of acetic acid.
27·5	"	chloride of ammonium.
24·2	"	carbonate of potassa.
24·2	"	carbonate of lime.
19.1	"	acetate of lead.

NEW MORDANTS.

The composition of the three subjoined mordants is that given by M. D. KŒCHLIN in his memoir on red mordants.

Mordant, No. 1.

In twenty-two gallons of water dissolve—

88·0	pounds	alum.
8·8	"	crystals of soda—carbonate of soda.
88·0	"	acetate of lead.

Mordant, No. 2.

In twenty-two gallons of water dissolve—

60·0	pounds	alum.
6·0	"	soda crystals.
44·5	"	acetate of lead.

Mordant, No. 3.

In twenty-two gallons of water dissolve—

44·5	pounds	alum.
5·0	"	crystals of soda.
29·7	"	acetate of lead.

The following is the process adopted in the preparation of these mordants:—Into a tub containing the alum, previously pulverized, is poured the quantity of warm water required for its solution; then add to the liquor thus formed the carbonate of soda, and lastly the acetate of lead. The effect of this latter salt, which is very soluble, shows itself instantaneously; an abundant precipitate of sulphate of lead is formed. Care should be taken to agitate the whole without interruption for one hour at least, and afterwards, from time to time only; but leaving the vessel uncovered that the cooling may be as rapid as possible, for it has been observed that when the cooling is slow, the acetate being long exposed to the contact of the air, there is always a certain quantity of alumina set at liberty, which does not dissolve again. When the carbonate of soda is introduced in the preparation of red mordant, it is not a matter of indifference whether it be added to the solution of alum or to the liquid which results from the double decomposition of this salt by the acetate. In the first case, it acts on the sulphuric acid of the sulphate of alumina, and its effect is to saturate the alum and to form with it cubic alum. In the second case, on the contrary, it exerts its action on the acetic acid, giving rise to proportional quantities of acetate of potassa or soda, according to the nature of the acetate. Such a mordant may be considered as basic, and more or less deliquescent. When the mordant has cooled, and the deposit of sulphate of lead is formed, the clear portion is decanted, and is put, to be preserved for use, in vessels of glass or very compact stoneware; as for the precipitate, it is put to drain on a cloth on which it is edulcorated, and the washing waters are used for the preparation of weak mordants, or for a new operation with the same mordants.

Mr. JOHN MERCER states that the true red mordant for calico-printing is made with alum and acetate of lead or lime, *without* any chalk, carbonate of potassa, or soda; for if one of these were present, the sulphuric acid would be taken up without the possibility of its being supplanted by acetic acid. It has been proved by experience in England, that not more than two out of the three equivalents of sulphuric acid in combination with the alumina should be removed, to form a good basic sulphate. The neutralizing substance must be an acetate having the same base throughout, and next to the acetate of lead is that of lime. Alum and acetate of lime have long been generally employed in England, and they yield nearly the same and quite as good results as KŒCHLIN'S tribasic sulphate of alumina dissolved in acetic acid. Four pounds of alum and three pounds of acetate of lead are usually taken for standard red liquor, which will require six quarts of water to reduce it to working strength. Acetate of lime at 14° or 15° Twaddell, heated with three pounds of alum crystals, affords the red liquor of commerce.

For pale red mordant, only one-half of the sulphuric acid must be extracted.

It would seem, at first view, that there ought to exist in all establishments a *mother* mordant, with which all the others might be prepared by diluting it more or less with water, and making additions to it of substances suitable for the different shades; however, such is not the custom of dyers and printers, who, for the most part, prefer to prepare several kinds of mordants which differ as well in their density as in the proportions of alum and acetate of lead employed, being guided in this by the following considerations:—

1. There are few shades for which a very strong mordant is required, or one demanding a greater quantity of acetate of lead than a mordant of mean density.

2. This last, into the preparation of which less acetate of lead enters, keeps longer than a strong mordant, which soon, by decomposition in the cold, depositing more subacetate of alumina than the mordant of mean density, would not always give a constant result when diluted with water.

3. A strong mordant, in which the acid acetate predominates, would not suit in several styles of printing, especially in that which consists of two or three reds where mordants of different density are printed one on another, because then the mordants getting confounded together would produce less distinct tints.

4. The mode of giving consistence to a mordant, or of thickening, varies according to the kind of printing for which it is intended, and an acid mordant cannot be inspissated so easily as another, with any of the substances which are employed for that purpose.

5. A strong and acid mordant is less easily discharged by the operation of dunging.

In many calico-printing works in the neighborhood of Paris and Rouen, they use, for the preparation of the red mordants, sulphate of alumina, which is now manufactured in pretty large quantities. As it occurs in commerce it contains—

	Centesimally.
Sulphuric acid,	33·178
Oxide of aluminum,	17·820
Water,	49·002
	100·000

It requires, therefore, seventy-five parts of acetate of lead to effect its partial saturation, and one hundred and eighteen parts of this same salt to render the double decomposition complete, and in order that all the sulphuric acid may be precipitated in the state of insoluble sulphate of lead. Nevertheless, these proportions of acetate may vary considerably, for, as has been already remarked, the composition of the sulphate of alumina is not always the same. It is certain that the commercial article contains different quantities of acid and of base, and the manufacturer cannot exercise too much circumspection in the use of this salt, especially for certain kinds of printing.

M. D. Kœchlin prepares the red mordant with the sulphate of alumina by operating in the following manner:—

To one hundred and ten parts of a solution of sulphate of alumina, marking 52° Twaddell when it is hot, and 56° when cold, he adds one hundred parts of acetate of lead dissolved in thirty parts of water; a double decomposition takes place between these two salts, and a solution of acetate of lead is obtained, marking 24° to 26°—the most concentrated which can be obtained.

There are print-works in which the acetate is replaced by an equal weight of acetate of lead; but when one does not wish to use either the one or the other, equivalent quantities of acetate of lime, baryta, or soda may be substituted, since

2375 pounds crystallized acetate of lead are replaced either by
1600 " anhydrous acetate of baryta, or by
1708 " crystallized acetate of soda, or by
1233 " anhydrous acetate of potassa.

Hitherto, it may be said that only the acetate of lime has been employed; it would be desirable, however, that the lead compounds were replaced in the preparation of mordants by less expensive substances. The oxide of lead which exists in the acetate represents more than two-thirds of the value of the principal substances which contribute to the formation of this salt, and in using it for the preparation of a mordant, it is transformed into insoluble sulphate of lead—a plumbiferous product, in which the lead has lost almost all its value, since it is turned to account at present only for the preparation of chrome-yellow and ceruse—carbonate of lead. It was formerly further utilized to make up the vats with plumbate of lime.

If commerce supplied the market with the acetates of baryta or lime in a state of purity, the manufacturer would find a great advantage in using them, because he would leave the sulphate of lime or of baryta, the product of the double decomposition, mixed with the mordant, and these salts would contribute as a mastic to the thickening of the color.

Instead of making the mordants by the way of double decomposition, which always necessitates the employment of an acetate, the mordant of which M. D. Kœchlin indicated the preparation has long been manufactured on the large scale, and the following is the process employed:—1. Neutralize a solution of alum, saturated in the cold, with carbonate of potassa, which is added by degrees with agitation till the flakes which are formed begin to be no longer redissolved. 2. Bring this neutralized solution to the boiling point, so as to cause the formation of basic sulphate of alumina, which is collected and afterwards treated with acetic acid, wherein it dissolves perfectly, especially in the heat, furnishing one of the strongest and most reliable mordants that can be prepared and employed. But it would be too troublesome to make this preparation on a small scale and in the works themselves, since it would be necessary to throw away the water from which the basic sulphate of alumina had been separated, and along with this water the sulphate of potassa, so that all the potassa of the alum, the whole of that which served for its precipitation, and lastly, a certain quantity of the alum itself would be lost. If, on the contrary, the fabrication of this product were conducted on the large scale in an alum factory, where the water more or less saturated with sulphate of potassa might enter again continually into a new operation, there would be no loss of alkali; the basic sulphate of alumina produced would be constant in its composition, dissolving well in the acetic acid; and in this case one would economize the whole of the potassa of the alum, which might be turned to good account, and all the oxide of lead, when the acetate of this base was employed.

If the hydrate of alumina of commerce were constant in its composition, and it were always equally attacked by acetic acid, it might thus be utilized with advantage by dissolving it in this acid, since it is demonstrated by the experiments of M. D. KŒCHLIN, that the acetate so prepared is an excellent mordant.

2. *Mordants in which the alumina performs the part of an acid.*—In treating of the preparation of aluminous compounds, the composition of the aluminate of potassa or soda has been stated; it only remains, therefore, to direct attention to the conditions in which the alumina can be separated from it, and made to combine with the goods.

This oxide, which plays the part of an acid, can only be displaced by an acid. This is a rule of displacement to which all bodies of this kind are subject. The acid employed for this purpose is the carbonic acid of the atmosphere; the fabrics impregnated with the aluminate of potassa or soda are exposed in this medium, in which the potassa or the soda of the aluminate, becoming saturated by slow degrees, sets the oxide at liberty; but this result will be arrived at much more readily, by placing the stuffs impregnated with mordant in an atmosphere charged artificially with carbonic acid, or even with acetic acid, and at the same time with much moisture. By operating as is done in the print-works, it is rare that the saturation of the alkaline base by the carbonic acid is complete—they always finish, too, by passing the stuffs charged with mordant into a bath of chloride of ammonium; the alkaline base then seizes on the chlorine, and the alumina and ammonia become free; for, as they form no combination with each other, the latter remains in solution in the water or is volatilized, according to the temperature, and the former is precipitated on the stuff. Nevertheless, this method of precipitation of the alumina is not the most advantageous; it is always preferable to prolong or render more energetic the action of the carbonic acid, because the alumina set at liberty by the chloride of ammonium has never the brilliancy of that which is deposited slowly.

Applications.—The mordants of alumina are employed alone or with other mordants, for the fixation of all the coloring matters which require an intermediate agent to constitute a color, and to become afterwards adherent to the goods.

FERRUGINOUS MORDANTS.—The ferruginous preparations, like the aluminous ones, only perform the part of mordants in so far as they are soluble, and cause a deposit of oxide of iron on the stuff. The study of them is highly complicated. Iron, in fact, presents several degrees of oxidation, and it is necessary to find, not only the saline combination which best gives up its base to the stuff, but further, that which possesses, in addition to this property, the degree of oxidation necessary to attract the coloring matters without injuring the goods. The fact must not be lost sight of, that, in depositing a ferruginous preparation on the goods, the iron may be combined either in the state of protoxide, which passes by little and little to the state of sesquioxide and even of ferroso-ferric oxide—Fe_3O_4; or in the state of sesquioxide, which may be hydrated, namely, in that in which it preserves its chemical condition, or anhydrous, exhibiting that modification in which it is, so to speak, unfit to perform any part; or lastly, in the state of a subsalt or insoluble neutral salt.

In a paper entitled, *Employment of pyroligneous acid in some operations of the arts*, and published in the *Annales des arts et manufactures*, M. BOSC examines in what state of oxidation iron should exist on the goods to serve as a base for black. According to this author, one should obtain on cotton a deep black tint, firm and brilliant, only in so far as use is made of a salt of iron with a base of black or protoxide, and the most favorable combination would result from the solution of the iron in acetic acid, because this acid, by the carbon which it contains, would prevent oxidation, and maintain the oxide at its inferior degree.

Arriving at the same conclusions, in a very extended memoir which treats of the fixation of the mordants of iron on cotton goods, M. H. SCHLUMBERGER establishes, first, that the acetate of iron obtained by several processes gives results very similar, and bases this proposition on the following experiments:—

He thickened with gum-water on the one hand, and with starch on the other, the following solutions of equal strength—10° Twaddell—*videlicet*,

The *first*, of acetate of iron obtained by the double decomposition of sulphate of iron and acetate of lead.

The *second*, of acetate of iron produced from a solution of iron in acetic acid.

The *third*, of acetate of iron produced by a solution of the metal in ordinary vinegar.

The *fourth*, of acetate of iron prepared by means of partially purified pyroligneous acid.

The *fifth*, of acetate of iron from which the tar had been separated by five minutes' boiling.

The *sixth*, of crude acetate of iron, containing a great excess of tar.

The *seventh*, and last, of crude acetate of iron mixed with the purified salt.

These compositions were printed in the same conditions on pieces of calico; each resulting sample was then divided into two and exposed to the atmosphere, one-half for two days only, the other for ten, before being submitted to the operation of dunging, and passed into a madder bath, when all gave a very fine violet, intense and very rich.

Although, from this result, it seems a matter of indifference which of these preparations is employed, M. H. SCHLUMBERGER points out those which should be preferred, in some localities, for certain kinds of printing. In every operation, in fact, requiring an oxidation of the protoxide of iron upon the fabric, the acetate is preferable. The crude salt, known also as the pyrolignite of iron, is more favorable for block-printing, in which the colors are exposed for a long time to the air, and where, consequently, the oxidation requires to take place slowly on the stuff; whilst the pure acetate should, on the contrary, obtain the preference for cylinder-printing, especially in those kinds of it in which the goods are immediately rinsed, and in which, consequently, the oxidation is performed rapidly.

Then advancing further, this chemist affirms, that if the acetates are oxidized before being applied to the stuff, the combination of the base with the fabric does not take place, and the iron is in great part, if not entirely, detached by the operation of dunging. If this proposition be taken in a limited sense, as embracing only the combinations of the acetic acid with the oxidized iron, there can be no difficulty in admitting it, for the sesquiacetate of iron may be considered as a solution of sesquioxide which exists in some sort in a free state, and is only fixed on the fabric with much more difficulty by reason that the acetic acid is disengaged before the salt is brought into immediate contact with the stuff. If, on the contrary, the proposition be taken in a general sense, as extending to all the salts of iron, it must be rejected as being the expression of a view which none of the following experiments confirm—experiments made by M. PERSOZ, and which do not appear to admit of any serious objection.

After preparing the sesquisulphate of iron of such purity that ferricyanide of potassium did not render the solution turbid, and that the latter, when boiled with pure oxide of copper, no longer contained any trace of iron in solution, he thickened with torrefied starch solutions of it, marking some 3° Twaddell, others 6° and 12°; he then had these solutions printed on samples of calico which were immediately dried at a temperature of 113° to 122°, then rinsed in a bath holding in suspension arseniate of lime and potassa, and lastly, dyed in a madder bath; and all these samples gave delicate violets, deep violets, and blacks, the full shades of which left nothing to desire. Experiments in every other respect similar, but in which the sesquisulphate was replaced by the protosulphate, afforded results infinitely less favorable both as regarded the shade, which was grey, and in respect to the quantity of color absorbed by the samples, and which had a bare appearance.

When an acetate is employed as a mordant, theory and practice direct that the protoacetate of iron be applied, in preference, to the goods, and this, by decomposing on the stuff, passes by slow degrees to the state of a basic salt, which oxidizes in the air; and, as it was desirable to inquire into the circumstances in which this oxidation might be effected without danger to the fabric, M. H. SCHLUMBERGER turned his attention to the question, and relates the result of experiments which he made on the four ferruginous preparations which follow, some at 24° Twaddell, and others at only 7°.

1. Acetate of iron obtained directly from the solution of iron in acetic acid.
2. Crude acetate of iron.
3. Acetate of iron obtained by the double decomposition of acetate of lead and sulphate of iron.
4. The same solution, but with an excess of acetate of lead added.

After printing these different solutions, gummed and not gummed, on as many samples as were necessary to study the different circumstances of oxidation, he exposed some, in a place with a mean temperature, to a moist air and diffused light; others in a warm situation, dry and darkened; others in fine to the rays of the sun and to all the atmospheric variations; and left in these different conditions the half of each of these samples for six days, and the other half for twenty-one days; then he passed them all into dung, to be subsequently cleaned and dyed, after which he found—

1. That the weakening of the stuff generally took place only in the samples on which the concentrated ferruginous solutions had been printed, and that in one case only, this weakening was remarked on the stuffs impregnated with a solution marking 6°;
2. That the goods were weakened by any of the four mordants mentioned above; less, however, with the last, containing an excess of acetate of lead;
3. That the pure mordants weakened the stuffs much more than those which were thickened with gum, starch, or fecula;
4. That exposure to the solar rays promotes in a given time the injurious effect on the goods, to such a degree that weak mordants, which do not attack the calico in darkness or in a diffuse light, deteriorate it very powerfully in the sun;
5. That in all the cases the weakening of the fabric does not decidedly show itself till the third or sixth day, but that at this period it is nearly the same as after the twenty-first day of the contact of the mordant with the stuff;
6. Lastly, that as the samples are passed into the dung at a boiling heat, or only at the temperature of 122°, and according as, on taking them out of this bath, they are or are not dipped into a dilute solution of chloroxide of calcium, the deterioration of the fabric is more or less decided; that is to say, it is scarcely perceptible if the samples have been cleared in a dung-bath heated to 122°, and if they have not been passed into bleaching powder liquor; and, on the contrary, it is always strongly marked when the same samples have been passed into the dung at a boiling temperature, or immersed immediately in the chloroxide.

After having thus shown, on the one hand, that this weakening of the fabric is due to the oxidation which takes place by reason of the quantity of protoxide which is deposited upon it, and on the other, that it is reduced to nothing when the mordants are weak, and is very marked when they are concentrated, M. H. SCHLUMBERGER explains this by the consecutive effects of the combination of the protoxide with the fabric, a circumstance involving disengagement of heat and electricity. M. PERSOZ accounts for this phenomenon by the fact of the momentary production of ferric acid—$Fe\ O_3$—which, as he ascertained by direct experiment, destroys the tissues with great energy when it is free in their presence.

Mr. MERCER has always considered oxygen as the cause of the *tendering* of the cotton just at the moment of its union with the protoxide of iron, and more especially when the metallic salt is in large quantity and intimately combined with the fibre. There are many instances, says Mr. MERCER, of other substances besides iron being the principal agent in the mordant, when this has taken place. A piece printed either with sulphate of iron of three pounds per gallon, or with one pound of the three converted into acetate by means of acetate of lead, then dried and passed through milk of lime, will be green; but when winced in chloroxide of calcium—bleaching powder—the iron is made buff, but the oxygen comes in such large quantity that the cotton involved is much weakened, and tears with the least effort, while the white parts of the cloth are not in the least affected.

Cloth padded with protoxide of tin dissolved in caustic potassa or soda is almost destroyed during the drying, so intense is the affinity of the mordant for oxygen.

If this same liquid, stannite of potassa or soda, be made very weak, and a strip of cotton cloth is hung half in and half out of the solution, the cotton soon becomes tendered at the surface of the menstruum, where the latter is in immediate contact with the atmosphere. This is the case when stannite of lime is substituted for that of alkali.

It is well known how difficult it is to prevent the cloth from being weakened in the Turkey-red process, by the rapid oxidation of the oil with which it is impregnated.

Many other cases of the same kind might be mentioned in which the stuff is tendered, evidently by the action of oxygen.

As it is the custom to add certain substances to the mordants with an iron base, with the view either of favoring the fixation of the sesquioxide on the cloth, or of preventing a too rapid oxidation of the mordant, or of opposing its too quick desiccation, or, lastly, of contributing to render its impression cleaner, something must be said on this subject. An opportunity will thus be afforded to speak of the researches which have been made by the scientific printer, whose experiments have just been recited, to account for the influence of these substances on the strong and weak ferruginous mordants.

The iron mordants for good blacks printed with the block have almost always a salt of copper—nitrate, sulphate, or acetate—added to them, which has for its object to facilitate the oxidation of the protoxide, and to hasten the combination of the sesquioxide with the fabric, and seems to possess, besides, the property of forming a combination with the latter, and preventing the passing of this last into that state in which it loses in some sense its chemical affinities.

The empyreumatic oil which crude acetic acid contains, and which establishes so great a difference between the acetates as regards the readiness with which they become fixed, has no other object than to retard the oxidation and prevent the action of the ferric acid on the stuff. The arsenious acid, which is employed in the violet and lilac departments, performs these two functions: on the one hand, it forms a combination with the sesquioxide, to which it preserves its chemical affinities, and, on the other, it retards the oxidation and prevents directly or indirectly the injuring of the fibre.

According to M. H. SCHLUMBERGER, the chloride of zinc which is introduced into the black mordant has no very sensible direct action on this preparation; but it opposes the tendency of the amylaceous matters employed as thickeners to coagulate; perhaps also it prevents, by combining with the sesquioxide, the isomeric modification of the latter.

The chloride of ammonium and the nitrate of potassa exercise an influence so important, that the success obtained by several manufacturers in certain kinds of printing is particularly owing to the introduction into the mordant of one or other of these substances employed in suitable proportion. Their effect appears to be, to fix the oxide more uniformly on the fabric.

The chlorates of potassa and soda perform a part nearly similar to that of nitrate of potassa.

Two ounces of saccharate of lime added to one gallon of violet mordant, render its shade clearer; first, because it precipitates a part of the oxide, and next, because the sugar more or less masks the salifiable bases. The same result is obtained with sirup of sugar—four ounces per gallon of mordant—with bitartrate of potassa, with tartaric acid, with lime juice; the action of all these bodies is precisely the same.

Oxalic acid does not injure the fixation of the iron, and two ounces of this acid per gallon of mordant do not change its shade. Acetic acid is not more opposed to it, and there are even certain operations in which its presence is necessary to maintain the oxide in solution.

Without adverting to the action of other substances, it will be sufficient in the meantime to state the results of the experiments undertaken by SCHLUMBERGER, with the view of establishing the proper degree of oxidation for obtaining ferruginous mordants of the finest fast shades.

It appears, from the researches of this chemist, that if, for fast impressions in black or violet, use is made of crude acetate of iron strongly charged with a tar which obstinately maintains the iron in the state of protoxide on the cloth, very bad results are obtained in the dyeing, whilst the same salt mixed with a certain quantity of acetate, prepared by the solution of iron in acetic acid, never gives any but good results.

To these two orders of facts—which demonstrate, the one, the inefficacy of a mordant too energetically maintained in the state of protosalt, the other, on the contrary, the efficacy of the mordant which is capable of passing to a superior degree of oxidation—SCHLUMBERGER adds others, which he adduces as affording unequivocal proof that a too advanced oxidation is always hurtful.

Thus, for example, after having steamed samples on which were printed mordants of violet and puce-color—mixture of iron and alumina—he remarked that these samples, when dyed and heightened, presented shades of a much more reddish tint than if the mordants had not been submitted to the action of the steam, which, nevertheless, appeared to him more hurtful to the puce mordants containing alumina, than to the black mordants with an iron base, and hence he concluded that this result is due to a more advanced oxidation; but PERSOZ thinks that there is here a misapprehension as to the part performed by the steam, which does not, in his opinion, set up any phenomenon of oxidation, but simply a change of physical state due to the heat, which renders indifferent a certain quantity of the oxides of iron and aluminum that are fixed on the stuff, and produce in this case, mixed with the violet—the sesquioxide, a kind of brown, and alumina, a less full shade.

Other samples, impregnated in like manner with mordants, and dipped, some into a solution of bichromate of potassa, others into a bath of bleaching powder diluted and heated to 104°, did not give better results; the tints of the samples passed into the bichromate were even more reddish than those of the specimens passed into the steam, which may be accounted for, when it is borne in mind that always when a stuff on which a protosalt is printed, is dipped into a solution of bichromate of potassa, there is a double decomposition, followed by deterioration, and consequently the formation of a compound which may be represented by a certain quantity of sesquioxides of chromium and iron; now, these acting as mordants, and the former producing brown shades, it is not surprising that one cannot obtain fine violets.

As for the action of the chloroxide of calcium, it is very simple: it modifies the physical state of the sesquioxide without changing its composition.

Foreseeing the objection, that the immersions in bleaching liquor and in bichromate of potassa, not only have the effect of oxidizing the iron, but further, by reason of the particular combinations to which they give rise, of modifying the ferruginous mordants, SCHLUMBERGER applied himself to other experiments on the mordants described in a preceding page, printing them pure or previously thickened, and exposing to the air samples of goods which were left so exposed—some for six, others for twenty-four hours, and others for two, ten, and twenty-four days.

He then observed, 1. That the mordants formed of acetate of iron—whether crude or pure—not thickened, produced on dyeing, after six hours' exposure to the air, colors which, considered in regard to their intensity, were as deep as if they had been left for twenty-one days; 2. That the same mordants, thickened, exhibited only slight differences in favor of those which were left open to the air during twenty-one days, differences which altogether disappear when one exposes for ten hours, instead of six, these same samples to the air before dyeing them; 3. That the mordants, the oxidation of which is effected in six, in ten, or in eight hours, give always, in dyeing, richer and purer tints than when these mordants have remained exposed for ten, and still more, of course, for twenty-one days, and that these differences show themselves more especially with the acetate of iron, which, not containing, like the crude salt, a substance capable of retarding its oxidation, produces always less favorable tints; and hence he concluded that it is neither sesqui- nor protoxide which is formed, but a combination of these bodies—in one word, ferroso-ferric oxide, Fe_3O_4—which is identical with that existing in nature, and known by the name of magnetic iron, or what is produced when steam is passed over the red-hot metal. In his opinion, this combination would possess sufficient stability to undergo, without losing any of its dyeing properties, the action of a temperature of 230° and even 280° Fahr. If it were so, by dissolving this complex oxide in an acid with the requisite precautions, one should find again in the solution a mixture of proto- and sesquioxides, which may be separated in several ways; for example, by boiling the solution containing the mixture of the two oxides with a certain quantity of oxide of copper, which has the property of precipitating the sesquioxide by seizing on the acid which holds it in solution, whilst it exercises no such action on the protosalt, the base of which is more powerful, and which should be found again in the liquor; but, at different times, M. PERSOZ dissolved in pure hydrochloric acid the ferruginous mordant fixed on a mordanted cloth, and never met with the protoxide in solution, after boiling it with the oxide of copper; which led him to believe that the iron exists in it in the state of sesquioxide, combined with phosphoric or arsenic acid, according as cow-dung or arseniate of lime and potassa were employed in the operation of fixing. Otherwise it would be difficult to explain how the mordanted cloth could receive, in SCHLUMBERGER'S experiments, the action of iron heated to 280° without the mordant losing its property of being dyed, which would inevitably happen if the iron existed in the state of free oxide.

According to Mr. MERCER, the best iron mordant is the crude acetate—pyrolignite—properly made, free from tar, but containing all the ethereal oils and spirit, as also the deoxidizing coloring matter, which prevent the too rapid oxidation of the iron. This mordant, combined with a proper quantity of white arsenic—arsenious acid—so as to form sesquiarsenite of iron as oxidation progresses and acetic acid evaporates, is the height of perfection for lilacs and fine plate work. The English purple plate styles from this mordant are unequalled.

To sum up, it may be affirmed, without fear of contradiction from experiment, that when solutions of iron obtained by acetic acid are applied on the stuff, with the view of making them perform the part of mordants, it is right that they be in the state of protoxide, in order that, the oxidation taking place on the cloth, there may be formed a basic acetate which will preserve to the sesquioxide its chemical properties, and pass to the state of phosphate or arseniate in the operation of dunging. It is necessary that this oxidation be slow and progressive, for, if it is rapid, the risk of the stuff being deteriorated, or of the sesquioxide passing into that isomeric state in which it becomes, as it were, indifferent to chemical agents, is incurred.

As for the other ferruginous compounds, all the acid salts are unfit to perform the part of mordants, while it is otherwise with the neutral salts, seeing that the protoxide which they contain, passing to the state of sesquioxide by absorbing the oxygen of the air, they no longer contain enough of acid to form a neutral salt, and consequently there is the formation of a basic salt which becomes fixed on the stuff. It is thus that one explains why the neutral protosulphate which remains on the calico yields to it always a certain quantity of its base, whereas, when it is acid, this phenomenon no longer presents itself. As for the sesquisalts, all those which, from any cause whatever, can pass into the state of basic salts, then become true mordants, capable of attracting coloring matters. The experiments related in a former page with samples A, B, C, D, E, apply here also; but it must not be forgotten that in all these salts the sesquioxide does not exist in the same state of condensation—that in some, as the phosphate and arseniate, there is only a very weak tint, and in others, as the nitrate, chlorate, and acetate, this hue is on the contrary very intense; now, it is demonstrated that in this last state the sesquioxide, having little affinity for coloring matters, gives only bad shades. When, for example, one imprints on the cloth a solution of sesquinitrate, the oxide which separates in the state of a basic salt is dyed with much difficulty, and produces only tints which are brown instead of being of a blue shade.

When the iron is in contact with the calico in presence of moist air, it produces, by oxidizing, spots of rust, which become fixed on the cloth, and attract the coloring matters. In the same circumstances, the protosulphide presents the same result, either from the circumstance that, passing first into the state of sulphate by an absorption of oxygen, it is immediately transformed into a basic salt by fixing a higher proportion of oxygen, or that it has directly the power of fixing by a double decomposition a certain quantity of coloring matter.

The alkaline mordants of Iron.—Hitherto few besides Haussmann have employed as mordants alkaline ferruginous solutions. He dissolved iron or its protosulphate gently in dilute nitric acid, under which conditions there was always the formation of an ammoniacal salt, which the Editor thinks the following equation explains:—

$$\underbrace{8\,Fe}_{\text{Iron.}} + \underbrace{19\,NO_5}_{\text{Nitric acid.}} + \underbrace{4\,HO}_{\text{Water.}} = \underbrace{5\,(Fe_2\,O_3, 3\,NO_5)}_{\text{Sesquinitrate of iron.}} +$$
$$\underbrace{NH_4\,O, NO_5}_{\text{Nitrate of ammonia.}} + \underbrace{NO_2}_{\text{Binoxide of nitrogen.}} + \underbrace{NO}_{\text{Protoxide of nitrogen.}}$$

The liquor obtained was afterwards saturated with carbonate of potassa, which was poured in very cautiously; the precipitate which formed at first was soon redissolved by an excess of carbonate of potassa, giving rise to a double salt which was decomposed by the alkaline oxides, these precipitating sesquioxide. Haussmann states that he used this solution with success in many circumstances.

Persoz is satisfied of the property which sesquiphosphate of iron possesses of being dissolved in the alkalies, and particularly in ammonia, so as to compose an excellent alkaline ferruginous mordant, which prints with clearness, and which may be dyed immediately after printing. If a solution of phosphate of soda —$2\,NaO, HO, PO_5$—be poured into a solution of sesquisulphate of iron, there is formed an abundant precipitate of sesquiphosphate of iron of a slightly yellowish-white, which being collected and washed, dissolves very well in ammonia. This solution being thickened and then printed, nothing more is required but to dry the goods briskly, to set up a combination between them and the mordant. When this has taken place, it is sufficient to rinse the goods in water, and to pass them afterwards into a bath of madder dye, to obtain the purest lilac and violet tints; and what is rather remarkable, is the circumstance that stuffs thus mordanted will even admit of being dyed in a spent madder-bath, in which fabrics mordanted in the usual manner would no longer be dyed—a result which must be attributed to the double decomposition which takes place in such a bath.

Applications.—The ferruginous mordants are employed alone, or mixed with those of alumina. In the first case they serve, with the red coloring matters, to produce on the stuff, greys, lilacs, violets, and blacks; with the yellow coloring matters, greys, olives, more or less deep, verging to black; and with a mixture of red and yellow coloring matters, a multitude of shades, from clear grey even to the deepest black. When associated with aluminous mordants, the ferruginous ones give, with red coloring matters, puce shades more or less intense, verging on black; with yellow coloring matters, yellows more or less olive, according as there is more or less of the iron mordants; with a mixture of red and yellow coloring matters, brown colors, dead leaves, rotten wood, *et cetera*, which vary *ad infinitum*, according to the respective proportions of the mordant of alumina and the mordant of iron, or those of the coloring matters of which the dye-bath is composed.

Stanniferous Mordants.—Tin by uniting with oxygen gives rise to well-marked oxides, one of which reacts as a powerful base, the other as an acid, and both of which are applicable as mordants. It may even be said, that of all the metallic compounds, the stanniferous combinations are those which adhere to the goods with the greatest energy. The best proof which can be given of this is, that even when a lake with an aluminous base is already formed on the goods, one can always remove the base, in whole or in part, by placing the stuff which is impregnated with this lake, under suitable circumstances, in presence of a compound of tin. The choice between a stannous and a stannic salt, is determined by the nature of the goods, and by that of the colors which it is desired to fix upon them. It will here be sufficient to consider the conditions in which these compounds must exist.

Of those which are employed for manufacturing purposes, there are some in which the oxidized tin performs the part of a base, and others in which it has the function of an acid.

I. *The compounds in which the oxidized tin performs the part of a base* are of two kinds: some having a base of protoxide, and others of binoxide. Among the former it is the protoxide which is in most general use; it cannot be deposited on the stuff without giving up to it a certain quantity of its base, seeing that when treated with water it undergoes a partial decomposition, and is transformed into an acid salt, which remains in solution in that medium, and into a basic insoluble compound which adheres to the fabric. Printers very often turn the salt to account along with a certain quantity of acid, to prepare the calicoes which they intend to receive the printing of *steam-colors*. As the chloride of tin employed in this manner acts only by a double decomposition which it produces in the water, whence there always results a certain quantity of hydrochloric acid, which becomes free, it is not uncommon to see stuffs, especially cotton stuffs, more or less injured by the acid. To prevent such accidents, one may apply with success, for the fixation of the protoxide of tin, the property which the acetates possess of acting in the manner of bases. For this purpose, when the goods have been padded in a bath of protochloride of tin, they are passed into one of acetate of potassa or soda, from which they are withdrawn by expressing them between two cylinders.

Bancroft employed, instead of chloride of tin, a solution of the protosulphate in hydrochloric acid, which decomposed still more easily in presence of the goods. The following is the manner of preparing this solution :—

On twenty-two pounds of granulated tin, introduced into a vessel of porcelain, stoneware, or glass, pour thirty-six pounds of hydrochloric acid of commerce, free from iron. Add by little and little to this mixture, 16·5 pounds of sulphuric acid at 150°; there is development of heat, and the tin is at first attacked with violence, but as it dissolves more slowly, in proportion as the liquor becomes concentrated, the mixture is heated, to complete the solution, in a sand-bath, until it disengages no more hydrogen gas. The whole being then left to cool, a saline mass is obtained, which contains a slight excess of tin; the liquor is decanted; the remaining metal is weighed to know how much has been dissolved, and this quantity being known, the liquor is diluted with just so much water that its weight may be eight times that of the tin dissolved, that is to say, one hundred and sixty pounds, for example, if there have been twenty pounds of tin dissolved.

These stannous salts—chlorides and sulphates—of which a great quantity is consumed, are often prepared in the print-works; but, from the difficulty of procuring vessels of stoneware or glass capable of bearing the action of the heat without cracking, these are substituted by tin boilers; and as these boilers themselves may melt when heated without sufficient precaution, M. J FRIES conceived the idea of covering internally a copper boiler with a thick coating of tin, which gave him two concentric boilers soldered together, the one of copper, to resist the action of the fire, the other of tin, to preserve the copper from the action of the acids.

These compounds are likewise prepared by raising to the temperature of 212°, in a water-bath, any quantity of Nordhausen sulphuric acid, in which is dissolved, to the point of complete saturation, protochloride of tin. The solution takes at first the consistence of a thick sirup, and afterwards the appearance of an indurated mortar. This preparation ought to be kept protected from contact with the air.

Among the compounds of binoxide of tin, there is a multitude of preparations which are employed as mordants or constituent parts of the lakes which are applied on the goods, and which contain binoxide, either pure or mixed with protoxide. They are generally designated by the name of *tin compositions*. Some of these are subjoined :—

1st. 22 pounds of tin in ribands are dissolved with precaution in a mixture formed of
55 pounds nitric acid and
120 pounds hydrochloric acid of commerce.

2d. 22 pounds of granulated tin are dissolved in a mixture formed of
44 pounds hydrochloric acid of commerce,
44 pounds nitric acid of commerce, in which has been previously dissolved
11 pounds chloride of ammonium.

3d. 22 pounds of tin in ribands are gradually dissolved in
176 pounds of nitric acid at 40° Twaddell, in which has been previously dissolved
22 pounds chloride of ammonium.

4th. 22 pounds of tin are dissolved in
22 pounds nitric acid at 62° Twaddell,
44 pounds hydrochloric acid,
44 pounds water.

5th. 22 pounds protochloride of tin are dissolved by degrees in a mixture formed either of
35 pounds hydrochloric acid, or
17·5 pounds nitric acid;

or of

17·5 pounds hydrochloric acid and
6·5 pounds nitric acid;

or, lastly, of

11 pounds hydrochloric acid, or
15 pounds nitric acid.

6th. 22 pounds protochloride of tin are gradually dissolved in
27·5 pounds nitric acid.

Further, in a mixture formed of—

7th. 22 pounds nitric acid, and
22 pounds hydrochloric acid,

as much tin is dissolved as these acids can reduce; and then heat is applied to dissolve in this liquor previously decanted,

2·2 pounds protochloride of tin.

8th. 22 pounds of tin are dissolved with caution in
42 pounds nitric acid at 64° Twaddell,
33 pounds hydrochloric acid at 36° Twaddell; the solution being effected, add
5·5 pounds acetate of lead.

Lastly, protochloride of tin is dissolved by small portions at a time, to the point of saturation, in nitric acid at 66° or 68° Twaddell. The resulting solution has the consistence of a jelly.

From these examples one may see how such preparations vary in their composition: it appears also that it would be more advantageous for the manufacturer to make them directly, by mixing bichloride of tin in suitable proportions with chloride of ammonium. As for the acetate of lead which is seen figuring in one of them, it has no other object than to diminish the corrosive action of the excess of acid which it contains.

The only preparations of tin used by English calico-printers are—

1. Protochloride of tin in crystals.
2. Protochloride in solution at 120° Twaddell.
3. Bichloride of tin in solution at 120° Twaddell.
4. Pink salt—chloride of ammonium and tin.
5. Stannite of soda.

These are generally purchased from the chemical factories in the neighborhood of the printworks.

II. *With reference to the compounds in which the oxidized tin performs the part of an acid.*—These mordants are of frequent use; they are prepared by dissolving protoxide of tin, or, for greater economy, protochloride, in hydrate of potassa or soda. These bases form with chlorine, alkaline chlorides, and the stannous oxide set at liberty combines with the excess of base to give rise to a soluble stannite.

This compound has but little stability; two powerful causes tend to decompose it. The first consists in the action exerted upon it by the carbonic acid of the atmosphere, which seizes on the alkaline base, and sets at liberty the protoxide of tin, which, uniting with the oxygen of the air, passes into the state of binoxide. The second cause is found in the disturbance of its molecules; for even when protected from contact with the air, the atom of protoxide divides into two, and is transformed into binoxide and metallic tin, according to the formula—

$$2\,Sn\,O = Sn\,O_2 + Sn$$

but the last, which remains entire so long as it is not exposed to the influence of the air, oxidizes when in presence of this agent, and passes by degrees to the state first of protoxide, and then of binoxide. Thus, in brief, from one or other of these causes, the stannite always furnishes to the stuffs which are impregnated with it, binoxide of tin. Further, as will be readily conceived, the displacement of the oxide is always favored by the intervention of the sulphuric acid, which, seizing on the base, sets the oxide at liberty, and accelerates its oxidation.

Applications of the Tin mordants.—Recourse is but rarely had to the mordants of tin to obtain *dyed* colors, or those termed *maddered;* they are only used to combat the effects of the iron or red mordants, or, after the dyeing is effected, to transform, by substitution, a lake with a base of alumina into another lake with a stanniferous base; but if the use made of them is limited in this department, they figure in almost all the so-called colors of *application*, and especially in *steam-colors.*

It is the binoxide of tin which gives to the coloring matter of cochineal that scarlet hue which no other colorless oxide can make it contract. With the tinctorial matter of madder it forms a fire-red lake, whilst a mordant of alumina produces, with the same matter, only a rose lake tending to violet.

Other mordants are likewise used to fix the colors on fabrics, as compounds with a base of sesquioxide of chromium. But although the latter oxide, isomorphous with alumina and sesquioxide of iron, is susceptible of adhering to the goods and attracting the coloring matters, it gives rise by its greenish-grey shade to lakes which are not clear in the colors, as will be seen by examining the tints obtained from this oxide, by passing the stuffs impregnated with it into a bath of Campeachy, Brazil-wood, madder, or quercitron.

These compounds, as well as those of some other metallic oxides, not being in general use, do not require to be minutely discussed in this place; and with reference to the fatty organic mordant which plays so important a part in the Turkey-red department, its action has been already examined in treating of that particular color.

STATISTICS.—In the Jury Report on that department of the Great Exhibition of 1851, which relates to the subject of this article, it is justly remarked that the art of dyeing has participated in the great industrial movement of the last twenty-five years; and of this the dyeing of mixed fabrics, composed of animal and vegetal substances, affords a striking proof. The great difficulty of presenting a bright, sound, and uniform color on fibres having different affinities has been overcome. In the various modes of dyeing silk and wool, Prussian-blue, with a tin mordant, has been substituted for indigo with complete success. The colors extracted from various dyewoods have, by a judicious application of oxidizing agents, been rendered brighter and more permanent. Preparations of tin, formerly employed for fine colors only, are now in general use, and furnish the means of multiplying the shades of bright and permanent hues.

The following table exhibits the amount of some of the most important dye-stuffs imported and exported during the last four years:—

	IMPORTED.				EXPORTED.			
	1852.	1853.	1854.	1855.	1852.	1853.	1854.	1855.
Cochineal, ...cwts.	22,042	10,160	19,341	27,478	8,964	11,178	14,475	13,691
Indigo,.................. "	83,565	66,409	70,173	59,760	67,184	59,588	50,550	64,167
Lac dye,................. "	17,631	18,050	16,871	9,424	6,955	6,053	4,627	6,121
Logwood, ...tons.	19,669	20,752	27,217	30,215	2,225	1,709	2,529	4,563
Madder,..................cwts.	84,385	111,563	102,723	100,251	..	..	..	..
Madder root,............. "	179,812	215,017	183,666	175,046	..	..	..	..
Sumach, ...tons.	9,758	10,836	11,524	13,082	..	..	..	..
Catechu,................. "	3,244	3,904	4,547	5,322	241	538	682	950
Cutch,................... "	2,236	485	1,915	2,361	528	456	510	975
Valonia, ... "	13,870	17,179	19,886	10.838	..	..	..	..

The duties on cochineal, after being reduced in 1842 to one shilling a hundredweight, were finally abolished, along with the duties on other dye-stuffs, in 1845. The consumption may perhaps be estimated at about twelve thousand hundredweight, or one million three hundred and forty-two thousand pounds. The price of this article has been liable to great fluctuations; in 1814, it was as high as thirty-six shillings and thirty-nine shillings for the best, and in 1853 it had fallen to from four shillings to six shillings and fourpence per pound. Previously to the war, which terminated in 1815, it had never been under twelve or thirteen shillings.

The consumption of indigo has varied but little in this country during the last ten or fifteen years, having been, at an average of that period, about two million pounds a year. This stationary demand, remarks the late Mr. MACCULLOCH, notwithstanding the fall in the price of the drug and the increase of population, is chiefly to be ascribed to the decreasing use of blue cloth, in the dyeing of which it is principally made use of. The following is believed to be a pretty accurate estimate of the average annual production of indigo in India, in maunds of eighty-two pounds:—

	Maunds.
Bengal,..............................	77,431
Tirhoot,.............................	23,168
Benares,.............................	13,775
Oude,................................	7,525
Total,......................	121,899

Of seven million eight hundred and ninety-four thousand four hundred and ninety-seven pounds of indigo imported into Great Britain in 1841, seven million four hundred and fifty-six thousand six hundred and seventeen pounds were from India, one hundred and four thousand one hundred and ninety pounds from the British West Indies, one hundred and seventy-eight thousand seven hundred and twenty-seven pounds from Guatemala, sixty-eight thousand three hundred and four pounds from Colombia, *et cetera.* Of the total quantity imported, two million seven hundred and eighty thousand five hundred and eighty-three pounds were retained for home consumption. The price of Bengal indigo of medium quality has varied at different times from three to six shillings per hundredweight.

Lac dye, which is the coloring matter extracted from *stick lac*, is formed into small square cakes, like those of indigo. Its use has been extending in this country, notwithstanding the continued fall in the price of cochineal. The annual consumption may at present amount to one million five hundred thousand pounds. The duty on this substance was formerly five per cent.; but in 1842 it was reduced to one shilling per hundredweight, and, as with other dye-stuffs, was totally repealed in 1845. The prices vary from one shilling and eightpence to two shillings and sixpence per pound.

Logwood is an article of great commercial importance. The entries for home consumption, at an average of the three years ending with 1842, amounted to eighteen thousand seven hundred and thirteen tons a year. The old duty of four shillings and sixpence per ton on foreign logwood, and of three shillings on that from a British plantation, was reduced in that year to two shillings a ton, and repealed in 1845. Its price in the London market varies from six to nine pounds per ton, according to quality.

The imports of madder are principally derived from France and Holland, and those of madder roots from France, Italy, and Turkey. A duty of six shillings per hundredweight on the former, and of three shillings per hundredweight on the latter, was repealed in 1845. The price of madder varies from twenty-five to sixty shillings per hundredweight.

Almost the whole of the sumach imported into this country is obtained from Italy. About ten thousand tons are retained for home consumption. The price varies from nine to eighteen shillings a hundredweight. The duty of one shilling a ton was repealed in 1845.

The duty on valonia, after being reduced in 1842 from twenty shillings to five shillings a ton, was repealed in 1845, with the duties on other dye-stuffs. The price of this article, of which it will be seen from the preceding table that a very large quantity is imported, varies from twelve pounds to sixteen pounds per ton.

It is difficult to procure reliable statistical information on the subject of dyed goods, except in connection with the art of calico-printing; and even on this latter subject, so important in a national and commercial view, there are no official returns. It is, therefore, fortunate that Mr. Edmund Potter, to whom the Editor has already acknowledged his obligations for many historical details of great value, has likewise devoted his attention to the statistical department, and has kindly authorized the Editor to freely avail himself of the facts which were stated in his able lecture before the Society of Arts in 1852, and of which, so far as relates to this subject, the following is a condensed statement:—

The present annual production of printed cloth of all kinds—namely, calico, muslin, delaines, in the woollen and cotton fabric, and printed woollens—is estimated by Mr. Potter at about twenty million pieces. He acknowledges that he arrives at this estimate with considerable difficulty, owing to the absence of any very authentic statistics. Commencing at the repeal of the duty in 1830, the excise return gives eight million three hundred thousand as the production of that year. In 1840, it was estimated to amount to about sixteen millions. Since that period, no means exist of coming to so accurate a conclusion. Mr. Potter's own experience, however, and that of others upon whose judgment he can fully rely, lead him to suppose that the present annual production exceeds twenty millions of pieces, and consumes a weight of cotton about one-seventh the entire import of the raw material into this country.

In reference to the exports of printed goods, the only information supplied is rather obscure, owing to their being classed with dyed cloths of all kinds; a custom which, it is hoped, may be altered, as producing unnecessary confusion. After much research and calculation, Mr. Potter ventures to estimate them for 1851 at fifteen million five hundred and forty-four thousand pieces, or rather more than three-fourths our entire production. These goods are, however, many of them, of the cheap and more staple class of prints, or slight goods suited to warm climates, and for markets where cheapness is the great recommendation. In value, he is disposed to estimate the export of printed goods at five million seven hundred and seventy-five thousand pounds.

In reference to the entire export of manufactured cotton goods—exclusive of yarns—it may be assumed that out of twenty-three million four hundred and forty-seven thousand one hundred and three pounds, given as the export of 1851, about one-fourth may be placed to the account of the print trade.

These exports may be divided, as nearly as is useful for the purposes of comparison and reference, amongst the following countries:—

ESTIMATED EXPORTS OF PRINTED GOODS FROM GREAT BRITAIN IN 1851.

	Pieces.
Hamburg and North Germany, large portion in transit,	900,000
Holland,	360,000
Belgium,	30,000
Denmark,	22,000
Sweden and Norway,	36,000
Russia—Odessa only,	14,000
France—in transit,	50,000
Naples and Sicily,	230,000
Sardinia, Tuscany, Trieste,	720,000
Turkey, Ionian Isles, Greece, Malta,	1,440,000
Egypt,	84,000
Gibraltar and Spain,	280,000
Portugal, Madeira,	410,000
Chili and Peru,	1,010,000
Mexico,	270,000
Brazils and East Coast of South America,	2,680,000
British West Indies,	660,000
Foreign West Indies,	690,000
St. Thomas,	450,000
British North America,	470,000
United States,	1,470,000
India,	1,570,000
China, Manilla, and Singapore,	550,000
Mauritius and Batavia,	325,000
Coast of Africa and Cape of Good Hope,	505,000
Australia,	237,000
New Zealand and South Sea Isles,	36,000
California,	45,000
Total,	15,544,000

The home consumption for 1851 was estimated at four million five hundred thousand; the excise returns for 1830 gave it as two million two hundred and eighty-one thousand five hundred and twelve pieces. The repeal of the duty, and the decrease in the cost of production, giving the consumer goods in much better taste and value at one-half the price, must have greatly tended to this increase.

The following is given as the number of print-works in Great Britain and Ireland, *exclusive of the London district*, in 1851:—

England—Lancashire,	120	= 202
Scotland,	81	
Ireland,	1	

The only records which Mr. Potter possessed of a former period were from a table compiled for private reference, by a friend in the trade, in the year 1840, and which he had then occasion to make use of and verify. This did not include London, and the numbers were—

Lancashire,	93 firms.
Scotland,	70 "
Ireland,	3 "

The Lancashire number shows an increase of twenty-seven firms, and Scotland of eleven, during that interval. This increase is comparatively small, when contrasted with that of the cotton trade generally, and it is really more insignificant than the figures represent, since the new establishments are almost all very small ones, many of them employed in printing the different fancy woollen and mixed fabrics, carpets, and yarns. It is an extraordinary fact, that for the last twenty-five or thirty years in the Lancashire district, no more than one or two new print-works of any great extent or power have been erected, while a greater number of large establishments have been discontinued. The power, then, by which the annual production has been raised from eight to twenty millions, has been chiefly gained by the extension of existing establishments; certainly the increase of producing power has been equivalent to the increase of demand.

There were three printing establishments in Ireland in 1840, but they have since been closed.

The rate of wages paid to the hands employed in the trade is believed to be higher than that of any other class in the cotton trade. Their occupation requiring from many of them a knowledge of chemistry and of art to some extent, and the constant exercise and appreciation of correct execution, enables them to rank amongst the highest class of manufacturing workmen.

Mr. Potter regrets that he can offer no official statistical returns as to the production of foreign countries. In connection with his office as reporter for the jury on printed goods in the Exhibition, he made every effort, through his friend, M. Persoz of Paris, one of his colleagues on the occasion—a gentleman whose varied knowledge on all subjects connected with French calico-printing cannot be too highly rated—to obtain reliable returns on that subject, but without success. The only estimate to which any reference can be made, is one of the late Mr. Thomson's in 1840, in which he calculates the then production of France to be little short of three million five hundred thousand; and if it be considered to have since increased one million, her trade of four million five hundred thousand pieces per annum—taking into view the high quality of a large proportion of her productions—may be ranked as a very important one. France, after ourselves, is placed highest in the scale in *value* of production, and next to the United States in *quantity*. She is, indeed, the only competitor which this country has to meet in any of the neutral markets of the world. This position she holds in fine goods only, and chiefly so by her taste. The United States exceeds France in *quantity* of production, and her consumption of printed goods is certainly more per head for her population, than that of any country in the world; but her printing is more remarkable for mechanical power and speed than for taste; her mode of business, forced in many instances by large capitals on the joint-stock system, varies completely from that of Great Britain. Her cost of production is also much higher, from her high-priced labor, coal, and drugs. She protects herself with a twenty per cent. duty, and competes with this country only in her own market.

The Zollverein, Austria, and Bohemia, produce for their own markets; and by their protecting duties prevent any other supply, except of very fine French goods. Their prints are good in execution, imitations of French taste in the finer goods, and of English prints in the medium and lower qualities.

Switzerland is very limited, but choice, in production, and opens her market to the world, with a fiscal duty of only two and a half per cent.

Holland has a small production of medium goods, and a very moderate protection, not exceeding five per cent. Belgium is highly protected, and produces nothing deserving notice in quality.

Naples has a few small print-works, and high protective duties.

Russia produces printed goods of no great character, and her market is prohibited to the British, except the port of Odessa. Spain likewise produces goods of an inferior quality to a limited extent, and prohibits imports, except in goods of a very fine quality, at a duty of fifty per cent. Occasionally, a large trade is done in English prints through the smugglers, chiefly from Gibraltar.

Portugal produces very slightly, and imports English goods at a duty of about thirty per cent.

Turkey produces a few printed goods, hardly worthy of criticism. Her duties are light—not above three per cent. Egypt has likewise revived the art, and with the assistance of European machinery and workmen produces the rudest possible results; duty as in Turkey.

Of the productions of all other countries, it may be fairly stated—with the exception of those of China, the East Indies, and the negroes—that they are imitations of either French or English goods, and cannot any of them be said to have a school of their own. The Chinese undoubtedly practised the art of calico-printing many centuries before it was known in Western Europe; but their productions exhibit a very primitive taste and rude execution.

In conclusion, Mr. Potter is inclined to think that the production of Great Britain in printed goods exceeds that of all the rest of the world.

ELECTRO-METALLURGY.—*Galvano-plastique*, French; *Galvano-plastic*, German.—This is the art of depositing metals from solutions of their salts, upon metallic or other conducting surfaces, by the agency of voltaic electricity; the metal thus deposited forming a compact body, similar to that obtained from the most improved metallurgical operation. Electro-metallurgy is a generic name, under which are included many specific processes, all more or less resembling each other, and dependent upon the same principles. In the earlier career of this very modern art, it was prosecuted chiefly as a pastime by thousands, under the name of the *Electrotype;* but it was not long confined to this superficial application, for by the skill and enterprise of such men as the ELKINGTONS of England, and RUHOLZ of France, it was speedily added to the industrial arts of both countries, and continues still to receive fresh developments in the number, usefulness, and beauty of its applications. Among these may now be enumerated its employment for the reduction of metals from their ores, for the analysis of alloys, electro-coppering, electro-silvering, electro-gilding, *et cetera;* for the multiplication of fac-similes of coins and medals; for copying seals and plaster casts; for making dies, busts, and statuettes; for obtaining, in metal, perfect copies to any extent, of various kinds of sculpture, of fruits, vegetals, insects, and other natural objects; for plain and engraved copper plates, steel plates, and woodcuts; for etching, and other important purposes, too numerous to be here detailed.

Although BRUGNATELLI experimentally practised gilding by galvanism in 1805, and more than thirty years afterwards, Professor DANIELL, when operating with his constant battery, and Mr. DE LA RUE, in the same circumstances, found that copper was deposited from its sulphate solution, and took the impression, however minute, of scars or scratches on the plate to which it adhered—yet it was reserved for JORDAN, SPENCER, and JACOBI, about the year 1839, to show the important applications of such phenomena to the arts. In fact, the art of electro-metallurgy may be said to date its origin from that period.

Its early history is interesting, and, as in many other cases, different claimants for the honor of the discovery have appeared; but before entering into any details on that subject, it will be desirable to place before the reader the principles on which it is founded. Even the facts of its discovery cannot be understood without a preliminary knowledge of certain electrical phenomena produced by chemical action, on which it is dependent for its existence, and of which it may be considered a branch. The name alone indicates its intimate connection with that mysterious agent which operates alike in the thunderstorm and the electric telegraph; which literally pervades all nature, as well as so large a department in the field of modern art; and which is, in fact, the motive power in electro-metallurgical operations. It is obvious, therefore, that, without a sufficient knowledge of the principles of galvanic action, or, in other words, of that development of electricity produced by chemical decompositions, the principles of electro-metallurgy cannot be intelligible to the reader; and hence the necessity of introducing the subject with a summary of the nature of galvanism and galvanic batteries.

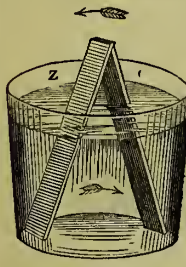
GALVANISM.—This term, which, as already stated, is applied to that development of electricity produced by chemical action, is derived from the name of its discoverer, GALVANI, professor of anatomy at Bologna, whose experiments on the convulsive effects produced by electricity on the muscles of dead animals, first drew attention to the subject. It is also termed *voltaic electricity*, in commemoration of the discovery of the voltaic pile by Professor VOLTA, of Pavia, who first established the identity of galvanism and ordinary electricity.

The history of the discovery of galvanism is not a little remarkable. The brilliant series of discoveries which had been made by the electric machine and batteries of Leyden jars had just ceased to excite the philosophical world, when the following singular circumstance is said to have occurred. Madame GALVANI had been in declining health, and was directed by her medical adviser to try the nutritive effect of stewed frogs. A dish of these animals, already dressed for cooking, lay on the table at the same time that a few of the Professor's pupils were amusing themselves by taking shocks from an electric machine. Madame GALVANI, keeping her eyes upon the delicate morsels, was struck with the frogs exhibiting convulsive movements when the machine was in action; she also observed that the blade of the knife which lay upon the edge of the dish touched some of the little animals. She kept her observation private till the return of her husband, who was delighted with the information, repeated and varied the experiments, and thus laid the foundation of the science of galvanism. This is one account of the matter. It is stated, however, by GALVANI himself, in a work published at Bologna in 1791, for the Institute of Sciences, that he was dissecting a frog on a table, whereon stood an electric machine, when the limbs suddenly became convulsed by one of his pupils touching the crural nerve with a dissecting-knife at the instant of taking a spark from the conductor of the machine. The experiment was repeated several times, and it was found to answer in all cases when a metal conductor was connected with the nerve, but not otherwise. He observed that muscular contractions were produced by forming a connection between two different metals, one of which was applied to the nerve, and the other to the muscles of the leg. This observation was made in 1790, and similar phenomena having been found to arise when the leg of the frog was connected with the electric machine, it could scarcely be doubted that in both cases the muscular contractions were produced by the same agent. GALVANI, who had long entertained the opinion that muscular action is attributable to electricity, looked on this phenomenon as a confirmation of that peculiar opinion, and pursued the inquiry with great zeal. From a course of experiments he drew the erroneous inference, in accordance with his preconceived hypothesis, that the muscular contraction was caused by animal electricity, that the muscle and the nerve were in the condition of the inside and the outside of a charged Leyden jar, and that the metallic connection merely served the same purpose as a discharging wire, by giving the two electricities the means of combining.

Galvani's investigations on this subject were no sooner made known to the scientific world, than they excited general interest; his experiments were varied in all possible ways; but his conclusions were objected to by many philosophers, among whom was Volta, who, from his researches, came to the conclusion that electricity was the effect of contact of dissimilar metals, and by arranging a series of zinc and silver plates formed what is termed the pile of Volta, or the voltaic pile. This apparatus greatly extended the means of producing electrical phenomena. All the combinations, indeed, now known as galvanic batteries, spring from, and may be considered as modifications of Volta's pile, which was discovered in 1800.

To illustrate the nature of the action in these galvanic arrangements, the simplest process is to take two plates of different kinds of metal, and place them in a fluid capable of exerting some chemical action on one of the plates, while it has little or less action on the other, and then to establish a communication between them by their direct contact with one another, at some point either above or beneath the surface of the liquid. Thus, let a plate of zinc and a plate of copper be partially immersed in dilute sulphuric acid, contained in a glass vessel, and let it be supposed that, in the first place, no communication is established between the two plates. In this case the zinc, being the more oxidizable metal, becomes rapidly dissolved, while the copper remains unaffected; an extrication of hydrogen appears at the surface of the zinc, arising from the decomposition of the water, the oxygen of which unites with the metal, forming oxide of zinc, which is immediately dissolved in the sulphuric acid, so as to expose to the water a new surface of metal. The fact has been clearly ascertained, that by this chemical action between the zinc and the liquid, the electrical equilibrium is disturbed; part of the natural electricity of the zinc passes to the water; in which it goes on accumulating until it arrives at its maximum tension, having no means of escape, but having at the same time a constant tendency by its accumulation in the fluid to check the chemical action. If, now, the two plates be inclined, so as to touch each other, as shown in Fig. 410, where C represents the copper, and Z the zinc plate, the chemical action will be found to proceed more rapidly—a fact explained by the circumstance, that the negative metal, copper, is thus brought into communication with the positive metal, zinc, so that the electricity which passed from the zinc to the liquid, now escapes from the liquid to the copper, and back again to the zinc at the point of contact between the metals, thus keeping up a constant current of electricity so long as the chemical action proceeds. In this case, also, after the contact is effected, the hydrogen gas, instead of being disengaged as formerly from the zinc plate, is found to be extricated at the copper surface. The copper being negative to the zinc, attracts the positive hydrogen, while the negative oxygen of the water combines with the zinc, forming an oxide of that metal, which, as already stated, is dissolved by the sulphuric acid.

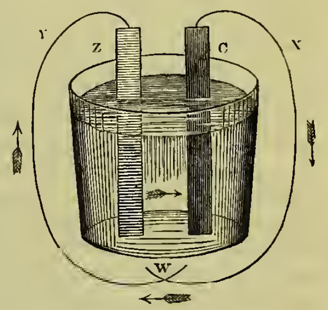
Fig. 410.



This experiment illustrates what is termed a *simple galvanic circle*, and the liquid in this case corresponds to the fluids in those parts of the leg of the frog that are brought into contact with the metals in Galvani's experiment. The action in both cases is the same. The liquid or fluid operates on the more oxidizable metal, which imparts to the former a portion of its electricity, and this is conveyed round in a circle by the other metal.

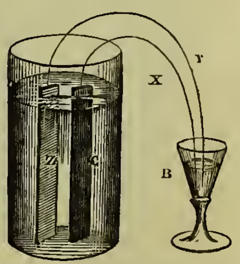
It has been assumed in the experiment above-mentioned, that, to complete the galvanic circle, the zinc and copper plates are brought into actual contact. This, however, is not necessary; any communication established between them by means of some conducting medium is quite sufficient. This communication may be effected by wires extending from the one to the other, as shown in Fig. 411. These wires may be of any metal, but copper being one of the best conductors, is usually employed for this purpose. The circuit is lengthened by this means, but the chemical action and the course of the electricity continue the same. The latter, as shown by the arrows, passes from the zinc to the liquid, through which it is communicated to the copper, and thence by the wires X and Y, which are supposed to be placed in contact at W, it returns to the zinc plate, Z.

Fig. 411.



This is still a simple galvanic circle. The wires have no action, except as conductors of the electric fluid. They admit also of directing the electric current through such bodies as it may be desired to subject to its operation, or of interrupting or renewing at pleasure the communication between the metallic plates, supposing the latter to be fixed in a frame, as in other forms of the apparatus to be noticed afterwards. For example, by disconnecting the wires at W—Fig. 411—the current ceases, or by introducing the ends of the wires into a fluid in the glass, B—Fig. 412—without bringing them into actual contact, the electricity will pass through the fluid from the wire, X, to the wire, Y, and thus the circle will be completed. When the action is sufficiently powerful, certain fluids, such as sulphate of copper, may thus be subjected to decomposition, and hence, in this case, the

Fig. 412.



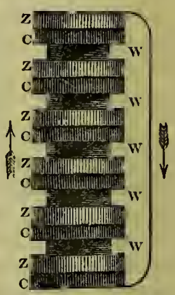
glass, B, is termed the *decomposition cell.* This is, in fact, a miniature form of the simple apparatus now usually employed in electro-metallurgical operations on the large scale. If the plates are of small size, the amount of electricity developed by this simple arrangement is very small; but by enlarging the size of the plates and increasing their number, as will be afterwards explained, their power may be indefinitely increased. A very large battery of this description, consisting of sheets of zinc and of copper, formed into coils, so as to encircle each other, and separated only by interstices of a quarter of an inch in width, was constructed by Dr. HARE, Professor of Chemistry in the University of Philadelphia, and which, from its remarkable power of producing heat, was termed by him a *calorimotor.* Mr. PEPYS constructed another for the London Institution, which consisted of only two plates, zinc and copper, coiled round a cylinder of wood, and prevented from coming into contact by ropes of horse-hair, which is a non-conducting substance. The metallic sheets thus coiled were each sixty feet long by two wide; and the whole was suspended over a tub of acid, so that by a pulley it could be immersed and removed.

Quantity and Intensity of Electricity.—Although, however, by enlarging the plates to any required superficial extent, the *quantity* of electricity developed by a simple galvanic circle may be proportionally increased, yet it is important to remark, that there are certain effects, requiring *intensity* of galvanic action, which cannot be produced by a battery of this description composed of a single pair of plates. The reader's attention is particularly requested to this distinction between electricity of *tension*, on the one hand, or electricity accumulated upon surfaces, and manifesting itself by attractions and repulsions, and by discharges passing through the air—and, on the other hand, electricity in *motion*, which manifests itself by its heating and decomposing power. The tension, or, as it is commonly termed, the intensity of the electricity produced by a simple galvanic circle, however large the superficial extent of the plates, is very trifling. It has little tendency to escape or to force its way through badly-conducting substances, such as air, or even pure water, or the resistance offered by a great extent of wire. At the same time its quantity may be great, and, if made to traverse a very fine metallic wire, the heat will be sufficient to fuse the most obdurate metals, and to exercise a most powerful decomposing effect, even when no spark can be elicited, and when the disturbance of the electric equilibrium cannot be detected by the most delicate instruments.

The quantity of the electricity put in motion by that arrangement which constitutes the simple galvanic circle, is dependent upon two circumstances—first, the size of the plates, and, secondly, the nature and strength of the interposed acid or liquid. Not only is the quantity augmented by increasing the superficial extent of the plates, but it is heightened likewise by increasing the strength of the acid up to a certain point. In the case of zinc and dilute sulphuric acid, for example, the more rapidly the zinc is oxidized by the influence of contact with the copper, and the oxide removed, so as to expose successive new surfaces to the action of the fluid, the greater is the quantity of electricity evolved. Still, so long as the arrangement is that of a simple circle, the intensity remains nearly the same; and to increase this, recourse is had to alternations of the metals and acid, which constitute a *compound galvanic circle.*

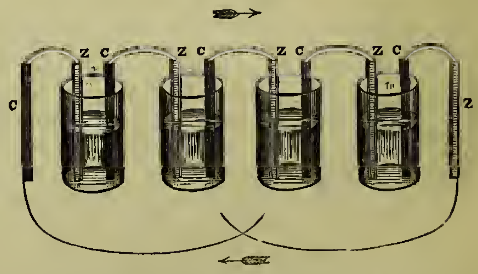
VOLTA'S PILE.—This compound arrangement introduces the *voltaic pile*, which, as already stated, constitutes in principle the common voltaic or galvanic battery. VOLTA, in prosecuting GALVANI'S experiments, discovered the principle of intensity by using a number of pairs of plates, moistened by a saline or by an acid liquid; and in 1800 he published a description of the apparatus or *pile*, which he had contrived for this purpose. It consists of a succession of pairs of plates of two dissimilar metals, such as zinc, Z, and copper, C, each pair being separated on either side from the adjacent pairs by pieces of bibulous card or of flannel, W, moistened with salt and water, or with very weak acid. VOLTA used silver instead of copper for the negative plate, and it will afterwards be shown that different metals may be employed in such combinations, though zinc and copper are generally the most convenient and economical. This apparatus was found to produce effects of a purely electrical character. On touching the ends of the pile with a finger of each hand previously moistened, an electric shock was experienced; sparks were obtained between two pieces of charcoal attached to the ends of the terminal wires; and when one of the wires was made to touch the cap of an electroscope, the gold leaves were found to diverge. In arranging the plates of the pile, a uniform order of succession must be observed. Thus, if a plate of copper, with a wire attached to it, form the bottom of the pile, a piece of wet card or flannel must be placed upon it, then zinc, then copper, then card or flannel again, and so on, terminating at top with a zinc plate, to which is attached the other end of the wire.

Fig. 413.



By bearing the above description in mind, the reader will perceive as he proceeds that this apparatus is simply a compound galvanic battery, in which the moistened pieces of card or flannel perform the part of the acid cells of the trough. VOLTA himself suggested a still

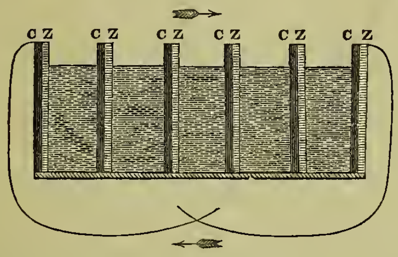
Fig. 414.



nearer approach to the latter, which he termed a *couronne de tasses*, or *crown of cups*, consisting of a series of cups or cells, containing an acid liquid, in each of which was a pair of plates of dissimilar metals, one of which, such as the zinc, was made to communicate by a wire with the copper in the adjacent cell. In this arrangement, shown in Fig. 414, the fluid in the cells performs the part of the moistened pieces of flannel, and operates with greater effect for a longer period. It is, in short, the galvanic battery in all its essential parts, and nothing remained but to give it a more convenient form, and by certain improvements of detail to economize the material.

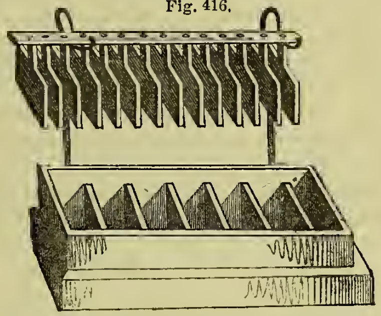
CRUIKSHANKS' BATTERY.—The first step in this direction was made by Mr. CRUIKSHANKS of Woolwich, who constructed the first *trough battery.* Adopting VOLTA's idea, which was generally received at the time, and is still supported by the German school, namely, that the contact of dissimilar metals was the cause of the electric action which the pile exhibited, CRUIKSHANKS soldered together each pair of zinc and copper plates, with the view of insuring intimate contact between them. The plates were of a square form; and the pairs, thus soldered together, two and two, by their flat surfaces, were fixed into water-tight grooves in the sides of a trough of baked wood, at the distance of about a quarter of an inch from each other, so as to constitute water-tight partitions, dividing the trough into a series of narrow cells between every pair of plates, which were filled with a solution of chloride of sodium, or a mixture of acid and water. The plates being so arranged that all the zinc surfaces faced one end of the trough, and all the copper the other, it followed that the series was terminated at one end by a copper, and at the other by a zinc plate. These terminal plates, being brought into communication with each other by copper or silver wires, completed the circuit, as shown in Fig. 415, which is a sectional view of the apparatus.

Fig. 415.



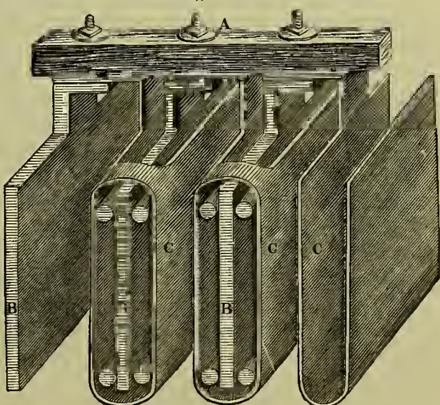
BABINGTON'S BATTERY.—In point of compactness, CRUICKSHANKS' battery was a very considerable improvement on the *couronne de tasses*; but still it was attended with great practical inconveniences, arising from the difficulty of cleaning or renewing the plates, the necessity of pouring out the fluid to arrest the chemical action, and other causes. A modification, suggested by Mr. BABINGTON, obviated these disadvantages. In this arrangement—Fig. 416—the trough, which may be of wood or earthenware, is divided by a series of partitions of the same material, into as many compartments as there are pairs of plates to be used. The zinc and copper plates are united in pairs, as in CRUIKSHANKS' battery; but instead of being soldered together by their flat surfaces, each of the pairs is united at one point only by a slip of metal passing from the one and soldered to the other, so that when the connecting slip is bent round in a U form, the faces of the plates are parallel to each other, but do not touch. The plates are connected together by a slip of baked wood, and are so arranged that when let down into the trough, a zinc and a copper plate of each adjoining pair pass into the same cell. By this arrangement, the plates and the fluid being independent of each other, the former may be taken out and readily cleaned, or replaced when injured, without disturbing the fluid; and the latter may, in like manner, be removed and changed, or the action may be suddenly arrested by merely raising the plates.

Fig. 416.



WOLLASTON'S BATTERY.—The last improvement on the common galvanic battery which it is important to mention, as having in fact given it the form now most generally in use for electro-metallurgical operations, was suggested, in 1815, by Dr. WOLLASTON, who found that the power of a battery was much increased, and a great economy in the quantity and wear of the zinc was effected, when both surfaces of each plate of zinc were opposed to a surface of copper. To effect this, the copper plate, C, was extended and bent round, so as to encompass the plate of zinc, Z, as shown in Fig. 417, while a slip of the copper at one side was connected with the zinc plate in the adjoining cell.

Fig. 417.



Battery now used.—The form of battery now in general use for electro-metallurgical operations on the large scale, is exactly Wollaston's in principle, but with a slight modification upon the original construction in the manner of adjusting the bent copper plates. By the arrangement represented above, when amalgamated zincs are used—as will be explained afterwards—small quantities of the amalgam of zinc fall from the zinc upon the copper, which interfere with the action of the battery by forming a new amalgam with the copper plates, thus causing a considerable loss of electrical power, and also of copper and mercury. To prevent this, the double copper plate, *a a*—Fig. 418—is now inverted, so as to be open below, while the neck or connecting bend, *b*, is above the zinc, and the part, *c*, is bent back, and fixed by a binding screw to the zinc in the next cell. This arrangement is shown in Fig. 419, where P P denotes the partitions of the trough; Z, the zincs; C, the bent copper plates; and *w w* the wires attached to the copper plate at the one end, and to the zinc plate at the other.

Fig. 418.

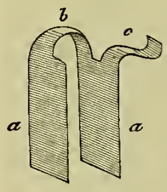
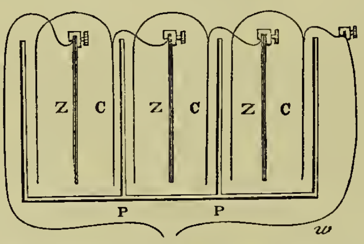


Fig. 419.



Although the common trough battery, constructed on Wollaston's plan, with the modification just mentioned, appears to admit of no essential improvement, yet it is attended with certain defects which seem to be inseparable from all batteries composed of similar materials. In the first place, assuming that these are zinc, copper, and dilute acid, the water of the latter can only dissolve a given quantity of sulphate of zinc, acting most freely at first, and therefore, as the action of the battery proceeds, the solvent power of the water decreases and affects the action of the battery. Secondly, a portion of the sulphate of zinc, which is being continually formed, is occasionally reduced upon the surface of the copper, thereby weakening the electric current, both by inducing a *local* galvanic action at the copper surface, and by tending to send a current of electricity in an opposite direction to the main current. In the third place, the copper becomes covered over with oxide and other impurities, which impair the action, unless the plates are frequently cleaned, which causes annoyance and interruption; and, fourthly, the hydrogen evolved at the copper plate adheres with considerable force to the surface of that metal, so as to prevent its direct and continuous contact with the fluid, and thus to produce the effect of a proportional diminution of surface.

It was to obviate these disadvantages that Daniell invented his *constant battery*, which, although attended with some inconveniences peculiar to itself, and not now generally employed in electro-metallurgical operations on the large scale, will ever be regarded with peculiar interest, *as having been the means of leading directly to the discovery of the art of depositing metals by electricity.* It is also peculiarly fitted for operating on the small scale, and as such it will always be a favorite with the amateur. An accurate description of this battery involves a complete elucidation of the principles of the electrotype, and therefore it must be given minutely; but before proceeding to do so, there are some collateral points of importance connected with galvanic action and galvanic batteries in general, which have been hitherto omitted to preserve the continuity of the narrative, but which it will now be desirable to introduce to the reader.

Positive and Negative relations of the Metals.—It has been remarked, in a preceding part of this article, that, to excite a galvanic current, two dissimilar metals must be brought into contact or communication with each other, and also with a fluid which acts more powerfully on one of the metals than on the other. Dilute sulphuric acid is the fluid, and zinc and copper are the metals, which have been hitherto selected as the types of this galvanic combination. These are the substances in common use, having been generally found the most convenient in point of economy and otherwise; but other metals and other fluids may be used, and are actually employed with advantage in certain forms of battery. In the zinc and copper combination, it has been remarked that the zinc is the metal on which the most powerful chemical action is exerted; indeed, when the metals are brought into communication, the whole of the action is found to be exerted on the zinc, and the copper is entirely inert, except as a conductor of the electricity, which passes from the zinc to the fluid, and thence through the copper back to the zinc. In this, or any similar combination, the metal which undergoes solution, such as the zinc, and from which the electric current proceeds, is termed the electro-positive metal; the other, which remains passive, or by which the electric current is simply conducted back to its source, is termed the electro-negative metal. These expressions are merely relative, not absolute; zinc is positive in this sense with regard to copper, but negative with regard to potassium; and generally, when acids and other fluids of an oxidating nature are employed, every oxidizable metal is positive with regard to a metal which is oxidizable in a less degree. Keeping this in view, the following is the relative order of the common metals in respect of their electro-positive and electro-negative properties, when immersed in water acidulated with sulphuric or hydrochloric acid—the metal relatively most positive standing first, and the most negative last—

Most positive.
1. Potassium.
2. Zinc.
3. Cadmium.
4. Tin.
5. Iron.
6. Lead.
7. Copper.
8. Bismuth.
9. Nickel.
10. Silver.
11. Antimony.
12. Gold.
13. Platinum.
Most negative.

Now, it will be seen that, as in any galvanic arrangement, each of the above metals is positive to all those that follow it in the list, any one of them, such as zinc, will be more positive to one that is separated by a wide interval, such as platinum, than to one that is nearer to it, such as copper or iron. Zinc and platinum will therefore make a stronger battery than zinc and copper; the latter will be more powerful than a battery with zinc and iron; and zinc and tin will furnish a very weak battery.

It is to be observed, however, that the order in the above list is not constant with all fluids, with all acids, or even with the same acid at different degrees of concentration. For example, in strong nitric acid, iron is nearly as electro-negative as platinum. When alkaline solutions are employed, the order is found to be nearly the same as that above given; but iron is again an exception, and occupies, in that case, a place intermediate between copper and silver.

The temperature has also a remarkable influence. Mr. GORE observed, for example, that tin is negative to iron at all temperatures between 62° and 203° Fahr. in distilled water, and positive to it at 212°; it is positive to iron at all temperatures between 62° and 212° in a saturated aqueous solution of boracic acid; also the same to iron between those temperatures in a strong solution of phosphoric acid in distilled water; or in one measure of sulphuric acid mixed either with nine or ninety-six measures of distilled water; or in a mixture of one measure of the same acid, and one hundred and ninety-two measures of distilled water from 73° to 158° Fahr., and negative to iron above that to 212°; it is positive to iron from 72° to 212°, in a mixture of equal measures of hydrochloric acid and water; it is negative to iron from 70° to 77°, and positive above that to 212° Fahr. in one measure of hydrochloric acid and nine measures of distilled water; it is negative to iron from 70° to 212° in one measure of hydrochloric acid and ninety measures of distilled water, and positive to iron from 68° to 212°, in one measure of hydrofluoric acid and nine measures of water; it is positive to iron in one measure of nitric acid and nine measures of water from 70° to 111°, and negative from 111° to 212°; and it is positive to iron from 82° to 212° in a mixture of one measure of nitric acid and ninety-six measures of water.

The same skilful electro-metallurgist remarked that iron is electro-negative to copper in the following liquids:—powerfully in a solution of sulphide of ammonium; feebly in a saturated aqueous solution of acetate of ammonia; in an aqueous solution of ammonite of copper, and increased by heating the liquid; in liquid ammonia, or in a saturated aqueous solution of ferrocyanide of potassium—each but for a short time —it then becomes positive; in a saturated aqueous solution of bichromate of potassa; in a strong aqueous solution of sulphide of potassium, becoming increasingly positive up to the boiling point of the liquid; lastly, in a saturated aqueous solution of hyposulphite of soda. Iron is negative to brass in a strong solution of sulphide of potassium, increasingly up to the boiling point.

These observations are interesting, and call for further investigation.

RELATIVE CONDUCTING POWER OF METALS.—On the whole, the preceding tabulated order of the positive and negative relation of the metals may be considered as constant with reference to the fluids that are generally used in galvanic batteries; but still, there are other considerations which must be taken into account in estimating the relative practical value of the metals for galvanic purposes. The most important of these is the power of freely conducting an electric current—a property in which lead, for example, is found to be very deficient. The relative efficiency of some of the metals in this respect, that is to say, their respective conducting power, is shown by the following numbers:—

Silver,	120	Platinum,	24
Copper,	120	Iron,	24
Gold,	80	Tin,	20
Zinc,	40	Lead,	12

It thus appears that, in respect of conducting power, lead stands at the very foot of the scale; it is also deficient in another important property, that of keeping a bright surface, and not becoming oxidized, the oxide destroying its conducting power; otherwise its mere position in the positive and negative scale would point it out as a cheap and efficient substitute for copper to form the negative plate. Zinc and platinum, according to the same scale, would constitute the best arrangement of all; and is indeed used with enormous effect in a battery which will be described afterwards; but while, on the one hand, the great expense of the platinum places it beyond general reach for common purposes, it will be observed that, on the other hand, copper has a marked superiority in conducting power. Silver is equal to copper in the latter property, and still more negative with regard to zinc; but, on the whole, zinc and copper are found to combine the advantage of economy with efficiency, in such a manner as to give them a decided preference for use in the common battery.

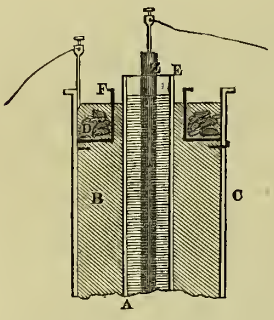
AMALGAMATION OF THE ZINC.—Whatever metal may be used for the negative plate, zinc is uniformly employed for the positive; and here it is important to observe, that an immense advantage is gained by previously forming the surfaces of both sides of the zinc into an amalgam with mercury. When a plate of the ordinary zinc of commerce is immersed in dilute sulphuric acid, the zinc is rapidly dissolved, and hydrogen gas is evolved in great quantity. But if the surface of the zinc, after being cleansed by immersion in the acid, be rubbed over with mercury, a brilliant amalgam is speedily formed over the whole face of the plate; and then it may be plunged into the acid without undergoing any chemical change for hours, so long as the galvanic circuit is not completed by bringing the zinc into contact or metallic communication with the negative plate. On the other hand, if this communication be established, the chemical action will proceed, and the amalgamated zinc will be dissolved, but much more slowly than before, and yet with a more abundant development of the electric current. It is therefore found highly conducive both to economy of material, and efficiency and constancy of operation, to amalgamate the zinc plates employed; and this is uniformly practised.

How it happens that the zinc when amalgamated does not lose in efficiency as much as it gains in durability, is not exactly understood; but it is attributed partly to the absence of what is termed *local action.*

The impurities of the zinc of commerce, containing an admixture of lead and other metals, positive or negative to each other, will naturally create conflicting currents, acting like an infinite number of small batteries, and these will proportionally diminish the main current of the battery. This explanation may be given as a definition of what is expressed by local action, which it is always an object of great importance to avoid. This may be accomplished to a certain extent by employing zinc perfectly pure; but such zinc cannot be procured without great difficulty; and the amalgamated zinc is not only prepared with facility, but is acknowledged on all sides to constitute the most efficient material that can be employed for the purpose. The best kind of zinc for the battery is that *milled* or *rolled* into plates, which should not be thinner than one-eighth of an inch; and if their size be upwards of four inches square, the best thickness is one-fourth of an inch. Cast plates of zinc are so porous, that no amalgamation will protect them from local action; they are also negative to rolled zinc, and are, consequently, less effective in developing the electric current.

DANIELL'S CONSTANT BATTERY.—The disadvantages previously mentioned, as belonging to all the forms of the common battery, and producing inconstancy of action, or a gradual decrease of power, in consequence of adhering hydrogen or a deposit of oxide, upon the negative plate, were overcome by Professor DANIELL, who published in 1836 an account of his *constant battery.* This battery, which is shown in section in Fig. 420, consists of an exterior vessel of copper, C, in which is placed a smaller vessel of porous earthenware or unglazed porcelain, E. Within the porous cylinder is suspended a cylindrical rod of amalgamated zinc, resting upon the rim of the porous vessel by a slip of wood passed through the upper part of the zinc rod. Binding screws are attached to the copper vessel and the zinc, and by means of a wire or slip of copper, a metallic communication is thus established between them.

Fig. 420.



To put this battery in operation, the porous vessel, E, is filled with an acid solution, A, consisting of one part sulphuric acid diluted with seven parts of water; and the space between this and the copper cylinder is filled to the same height with a solution of sulphate of copper, B, acidulated with one-eighth of its bulk of sulphuric acid. The solution is kept saturated with the salt by means of crystals of the sulphate, D, which rest upon the perforated shelf, F.

The action in this case is as follows:—The acidulated fluid in the porous vessel acts upon the zinc, as in the common battery, producing an evolution of electricity, which is conveyed through the porous vessel, as if no such obstacle intervened; but, at the same time, the sulphate of zinc which is formed in that vessel is prevented from mixing with the copper solution in the outer vessel. The electric current, in passing through the sulphate of copper, decomposes that salt, and instead of hydrogen being liberated from the surface of the copper, as in the common battery, it combines with the oxygen of the copper in the sulphate of copper, by which the copper is reduced in the metallic state upon the surface of the cylinder of that metal forming the outer vessel. Another advantage of this battery is, that the sulphate of copper has no tendency to act upon the copper itself, and thus to produce a counter-current. Accordingly, this arrangement was found to keep up a current of uniform strength for many hours, and to furnish electrical science with a battery of far greater power for its size than any which had previously been used.

The circumstance connected with this battery which led, by an almost necessary consequence, to the discovery of electro-metallurgy, is the action just referred to, namely, the constant deposition of the reduced metal from the sulphate upon the copper plate.

Any number of cells on this principle can be arranged and connected so as to form a battery of great power. Fig. 421 shows a convenient form of the copper plates, consisting merely of rectangular sheets of copper, *a*, bent into a cylindrical shape; and these, instead of being formed into vessels, may be inserted in glass or earthenware jars for holding the sulphate of copper. By means of the strip, *b*, each plate is easily connected with the zinc rod of the adjacent cell. The colander for supporting the crystals of the sulphate to keep the fluid in a state of saturation, rests upon little pieces or pins of copper which are made to project inwards upon the sheet, at a suitable height, as at *c*. Fig. 422 shows the manner in which a number of these cells may be arranged and connected in a consecutive series.

Fig. 421.

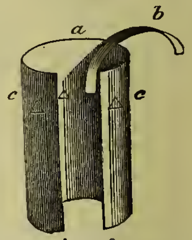
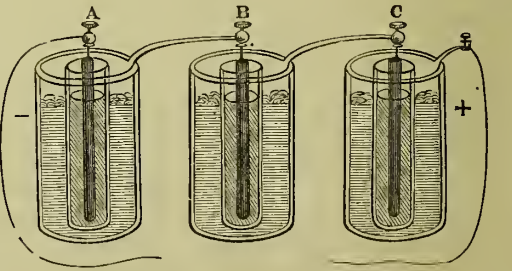
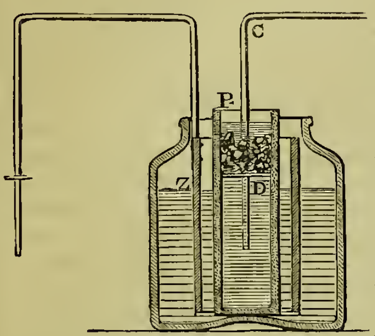


Fig. 422.



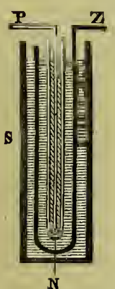
The relative position of the zinc and copper in this battery is evidently not essential, provided they are separated by the porous vessel, and each is immersed in its own proper liquid. Thus, in the arrangement represented in Fig. 423, which indicates the cell of a Daniell battery much employed for working the French telegraphs, Z is a cylinder of zinc, surrounding the porous vessel, N; within the latter is a copper diaphragm, D, charged with crystals of sulphate of copper; and the liquid external to the porous vessel is dilute acid. In this case the diaphragm, D, and a portion of the wire, C, act as the negative plate.

Fig. 423.



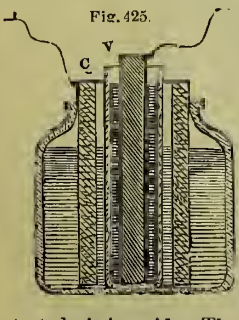
Grove's Battery. — Adopting the porous cell, but employing nitric acid instead of the copper salt, and platinum instead of copper, Grove constructed a battery of still greater power, although upon the same principle. In this battery the outer vessel, S—Fig. 424—is of glass or earthenware, in which is suspended a porous vessel, N, as in Daniell's. But instead of a rod of zinc, a slip of platinum, P, is inserted in the porous tube, which is nearly filled with *undiluted* nitric acid. The zinc, Z, in the form of a flat slip or sheet, bent, as shown in the figure, so as to infold the porous tube, is placed in the outer vessel, which is filled with sulphuric acid, diluted with ten parts of water. As platinum is the least liable of the metals to chemical action, and zinc is one of the most readily attacked by acids, while nitric acid absorbs with ease the hydrogen liberated at the platinum, and the resulting liquid is one of the most perfect fluid conductors, the action of this battery, when first excited, is very energetic in proportion to its size. It is the most powerful of all batteries, but is not so constant as Daniell's, and is not so well adapted for electro-metallurgical operations, in which intensity of action is much less important than constancy and quantity.

Fig. 424.



Bunsen's Battery.—This is simply a modification of Grove's, in which, with a view to economy, the platinum element is replaced by the cheaper material, charcoal. A solid cylindrical rod of this substance, made from the residuum taken from the retorts of gas-works, is placed in the porous vessel in contact with the nitric acid, instead of the slip or rod of platinum. Sometimes the carbon is in the form of a hollow cylinder, and is made by coking pounded coal in a proper iron mould. This arrangement is shown in Fig. 425, where Z is the zinc rod inserted in the porous vessel, V, containing dilute sulphuric acid, and C is the hollow cylinder of carbon immersed in concentrated nitric acid. The real Bunsen battery, however, is made by employing the coke vessel itself as the porous cell; and the arrangement in that case may be conceived by supposing the zinc rod, Z, to be removed, and that V represents the vessel of coke or carbon filled with nitric acid and sand, while in the place of C is a sheet of zinc bent into a cylindrical form, so as to surround the porous coke vessel, external to which is dilute sulphuric acid. By soaking the coke in sugar, and calcining a second time, great compactness is given to the rod or cylinder. This battery, when properly constructed, is not less efficient than Grove's, and is much used on the Continent and in America for working the electric telegraphs; but it is seldom employed for electro-metallurgical purposes.

Fig. 425.



Callan's or the **Maynooth** battery is another interesting modification of Grove's. Taking advantage of the remarkable passativity of cast-iron, in relation to a mixture of strong nitric and sulphuric acids, Professor Callan constructed his apparatus with cast-iron cells, in which a porous porcelain cell with a zinc plate is inserted. The latter contains dilute sulphuric acid; the former a mixture of the two acids just mentioned. This is a powerful galvanic apparatus, and the original cost is very small.

Smee's Battery.—It has been shown that one of the principal disadvantages connected with the common battery, is the obstruction occasioned by the hydrogen adhering to the negative plate. This is overcome in the Daniell and Grove batteries by chemical agency; in the former the sulphate of copper, and in the latter the nitric acid employed, absorb the hydrogen. Another method of effecting the same object, *by mechanical means*, was discovered by Mr. Alfred Smee, surgeon to the Bank of England, and the battery contrived by him on this principle is much employed by amateurs in electro-metallurgical processes. Smee observed that, though the hydrogen escaped with difficulty from smooth surfaces, it passed off much more freely when the copper plate of the common battery was roughened, either by corrosive acids, or by rubbing the surface with sand paper. Availing himself of this property of rough surfaces, Mr. Smee employs, as the negative plate of his battery, a plate of silver, the faces of which have been roughened by the deposition of finely-divided platinum upon its surface. The platinum may either be deposited by electro-chemical agency, after brushing over the silver with strong nitric acid, and then washing it, when, if it be placed in a vessel containing dilute sulphuric acid, to which a few drops of bichloride of platinum have been added, the latter metal will be thrown down in a pulverulent form; or the silver may be merely well roughened with sand paper, and then inserted in the platinum solution made very hot, when a similar deposit will be obtained.

Having thus roughened the surface of the silver with the platinum powder, Mr. Smee, in arranging the plates, reverses the order of Wollaston's battery, surrounding the more expensive silver with the positive zinc, so as to present a surface of zinc to each face of the platinized silver. The liquid employed is dilute sulphuric acid. Fig. 426 represents a battery constructed upon Smee's principle, and Fig. 427 shows the plates detached. S, in the latter figure, is a thin platinized silver plate, supported in a light frame of wood; to the upper part of this frame a binding screw in metallic connection with the silver, is fastened for the purpose of connecting the plate with the zincs of the adjoining cell, by means of a strip of sheet copper bent, as at C. Z, Z, are similar sheets of amalgamated zinc, which are supported on either side of the silver plate by a clamp, B, and are prevented from contact with it by the wooden frame; they are brought into metallic connection with the silver of the adjacent cell by a second binding screw in the clamp shown at B. The series of plates, thus arranged, are attached to a wooden frame, and being counterpoised by weights, as shown in the figure, or fitted, as in ACKLAND'S improved construction of this battery, with an iron rod and ratchet-wheel, can be readily elevated or depressed, so that the plates may be either partially or entirely immersed in the liquid, or altogether raised out of it when not required to be in action.

Fig. 426

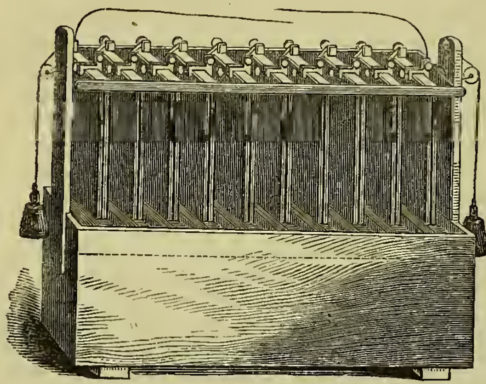
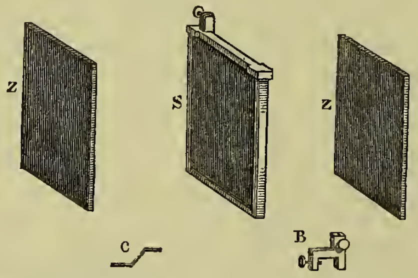


Fig. 427.



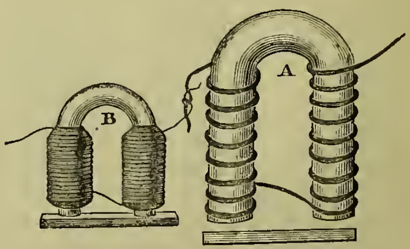
THE MAGNETO-ELECTRIC MACHINE.—Instead of voltaic batteries to supply the electric current to the metallic solutions, magneto-electric machines have been employed, and for various modifications of these several patents have been obtained. They are sometimes improperly termed electro-magnetic machines, from which, however, they differ as widely as magneto-electricity differs from electro-magnetism. The latter is magnetism derived from electricity; the former is electricity derived from magnetism; and this is the principle of the magneto-electric machine. It may be regarded, indeed, as a kind of battery; and having been employed in that capacity, both for electro-metallurgical purposes, and in working the magnetic telegraph, some account of the principle of its action seems to be a necessary appendage to the history of the various modifications of the galvanic or voltaic battery.

When OËRSTED, in 1819, discovered the connection between electricity and magnetism, by observing that a magnetic needle, freely suspended, was deflected at right angles to an electric current passing near it, the attention of philosophers was powerfully drawn to the subject, and AMPÈRE, in 1820, found that a bar of soft iron placed within a coil of copper wire, through which a current was transmitted from a voltaic battery, became magnetic, maintaining its magnetism so long as the current continued. If the bar, A or B—Fig. 428—is bent into the form of a horse-shoe, and the copper wire, covered with silk thread, or some other non-conducting substance, is coiled round each of its arms in the manner shown in the figure, a powerful temporary magnet will be formed by connecting the ends of the wire with the poles of the battery. In proportion to the power of the battery and the number of coils of the insulated wire, will be the degree of magnetism imparted. The magnetic power to be obtained in this manner with soft iron very far exceeds what can be permanently imparted to steel. An electro-magnet constructed by Mr. JOULE was shown in the Great Exhibition, capable of lifting a ton weight; and electro-magnets of larger size have been made that lifted several tons.

It occurred to FARADAY, that if magnetism was thus produced by a current of electricity, a current of electricity might be produced by magnetism, and accordingly he found that when a powerful magnet, instead of the bar of soft iron, was introduced into a coil of copper wire, the ends of which were connected with a galvanometer, a momentary current was indicated in the wire; and again, on withdrawing the magnetic bar, another momentary current in the opposite direction. When the bar was at rest within the coil there was no current. Its sudden introduction or removal was, however, clearly productive of certain electrical effects, to which FARADAY gave the appropriate name of magneto-electricity.

The scientific world was thus furnished with a new source of electricity, differing as much from the common electric machine, in which the development of the fluid is produced by friction, as it differs from the galvanic battery, in which the current is produced by chemical decomposition. This new source was magnetism; but to render the discovery available for any useful purpose, it was necessary to devise an arrangement by which a steady and continuous current, or something equivalent,

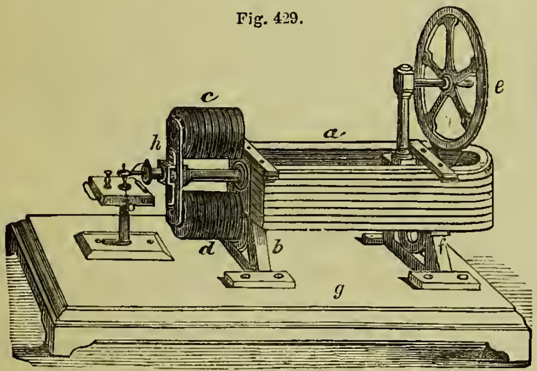
Fig. 428.



could be obtained, instead of successive momentary currents in opposite directions to each other.

The magneto-electric machine, in its most improved form, accomplishes this desirable object as nearly as possible. The essential parts and the general construction of this machine are shown in Fig. 429, where *a* is a compound permanent steel magnet, which acts in this case as the battery, or source of electric power. It is composed of several thin plates of steel, all of the same horse-shoe form, and separately magnetized and bound together—an arrangement which, by exposing a larger surface, is found to produce a much more powerful instrument than if the same quantity of steel were made into a solid magnet of the same form. This powerful magnetic battery is firmly fixed in a horizontal position on the supports, *b*, *f*, which are bolted into the stand or table, *g*. Within the coils of copper wire, *c*, *d*, which constitute indeed one continuous coil in two parts, are bars or rods of soft iron, which are formed into a kind of horse-shoe by the connecting piece, *h*, also of soft iron. The part, *c h d*, may therefore be regarded as representing a horse-shoe of soft iron, with numerous convolutions of the same copper wire round its two arms; and to send successive currents of electricity through this wire, supposing its two ends to be connected, it will only be necessary to magnetize and demagnetize alternately the core of soft iron within it, the same effect being thereby produced as if a permanent horse-shoe magnet were alternately introduced into the coil and withdrawn successively, as in FARADAY'S experiment above-mentioned. With this view the armature, *h*, is fixed on a spindle passing through the axis of the compound magnet, and connected with a small grooved wheel or pulley near *f*, which is worked by a cord or band over the larger wheel, *e*. By turning this large wheel, either by the hand or by any convenient power, the armature, *h*, may be made to revolve rapidly, and thus the cores of soft iron enclosed in the coils, *c*, *d*, are brought successively over against the two poles of the compound magnet, *a*, to which they are placed as near as possible without touching. It is well known that a piece of soft iron placed in the immediate vicinity of one of the poles of a magnet, becomes magnetic by induction, and each time, therefore, that the cores, *c*, *d*, pass in their revolution the poles of the magnet, *a*, they are strongly magnetized, whereas, when they return to the position shown in the figure, they lose their magnetism entirely.

Fig. 429.



Successive currents of electricity, alternately in opposite directions, are thus made to circulate through the coils, *c*, *d*; but it still remains to procure a current, or currents, as nearly as possible continuous in the same direction. To enter into the minutiæ of the different arrangements for this purpose, would not be consistent with the limits of this work; but it may be stated that there are two methods of doing so—either by suddenly breaking the circuit at the moment when the current has been established in one direction, and closing it again at that point of the revolution when the same current is resumed, or by making arrangements to reverse the polar relations of *c*, *d*, at the instant when the current is about to be reversed, and thus obtaining a rapid succession of currents or impulses in the same direction. The reader will readily conceive how this may be effected, either by connecting one end of the wire with a cup of mercury, into which the end of the wire from the other coil, connected with a metallic disc at the end of the spindle, as shown in the figure, dips during part of the revolution, so as to complete the circuit at certain regular intervals; or by connecting one end of the wire with springs pressing on interrupted collars of metal to which the other end is attached; and in that case either the spring or collar may be made to revolve, so as to complete and break the circuit alternately, or reverse the poles at pleasure.

It is not possible by this means to obtain a continuous current of electricity, as from the galvanic battery, but the impulses may be made to succeed each other so rapidly in the same direction, that an equivalent effect is produced for most practical purposes. To render the succession of impulses still more rapid, a number of compound magnets, with a corresponding number of armatures, may be employed. A compound machine of this kind, for which a patent was sealed in 1851, is erected at Messrs. ELKINGTON and MASON'S, and is represented in the annexed drawings—Figs. 430, 431, 432, and 433. In this machine, the iron frame, A A—Fig. 433—supports no less than eight permanent compound steel magnets, B B, which are either insulated from the frame, or placed at such a distance from it as to be perfectly free from its influence. One of the magnets, as detached, is shown in Fig. 021; it consists of eight plates of a U form, each weighing about thirty pounds. When arranged in the frame, the North poles are all placed on one side, and the South poles on the other.

There are sixteen armatures of soft iron, C C, four of which only are seen in the elevation, each weighing about fifteen pounds, and coiled round with sixty feet of insulated copper wire. One end of this wire is connected with the break-piece, D, on one side of the machine; while the other end is in contact, on the other side, with a small solid brass wheel, which, with the centre wheel, H,—to which the armatures are attached—is caused to revolve on the shaft, F, by means of a band, I, communicating with the shaft of the steam-engine. The armatures pass, in their revolutions, between the poles of the magnets, and as nearly as possible to each, so as not actually to touch them. Wires of copper which convey the current to the vats are represented by G.

The arrangement of the armatures and magnets is shown more in detail in Figs. 431 and 432, the former being a vertical section and the latter a plan of the centre wheel, with the armatures and magnets only.

Fig. 430.

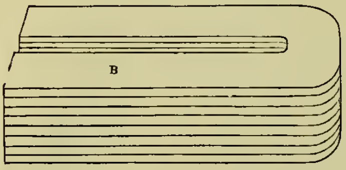
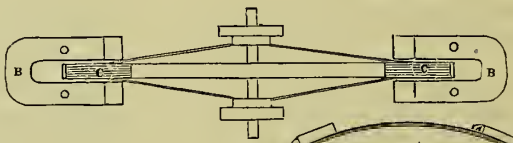


Fig. 431.



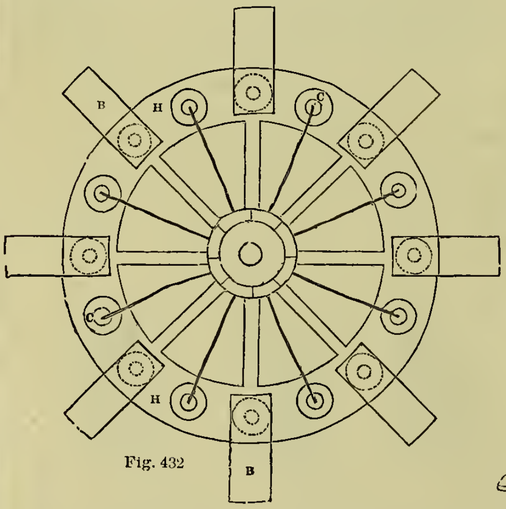


Fig. 432

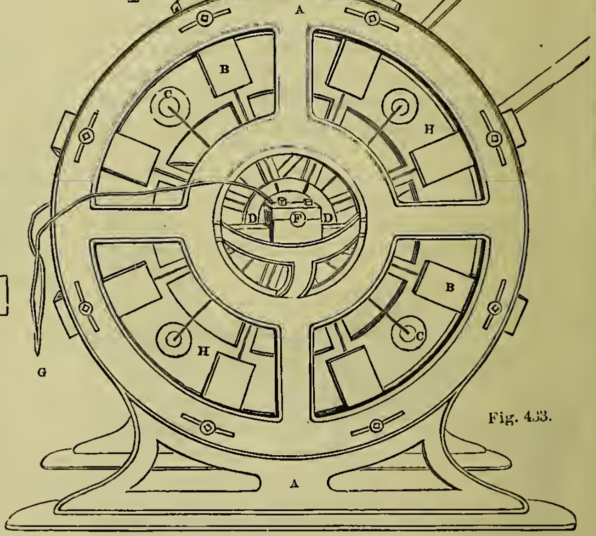


Fig. 433.

The induction of electricity by magnetism alone seems at first sight to open an exhaustless source for the supply of electric agency without the trouble, the annoyance, and the cost of voltaic batteries; but hitherto it has not been of much avail. Where steam power is wanting, the labor of turning the wheel for the rapid rotation of the armatures, and even where steam is available, the irregularity and impulsive character of the current produced, are serious drawbacks to the use of magneto-electric machines as the generators of electricity for chemical operations requiring steady action. As an economical means of exciting electricity for electro-plating and gilding, it was at one time thought to promise great advantage; but even with steam power at command, and a truly magnificent machine constructed upon the best principles, Messrs. ELKINGTON and MASON have not found it to answer so well as voltaic electricity, in consequence of the want of continuity and steadiness in the current. A similar machine has been applied, however, to work the needle telegraph with very good effect.

Definitions of Terms.—There are one or two terms employed to designate the different parts and materials of galvanic batteries, which may be occasionally used in connection with their application in the subsequent portion of this article, and which it will therefore be useful to define before proceeding to the practical details of the subject. The two extreme plates of a battery or voltaic pile, or the ends of the wires proceeding from these extreme plates, and immersed in a fluid or connected with any other substance through which the electric current passes from the one to the other so as to complete the circuit, are termed the *poles* or *electrodes* of the battery. The positive pole or electrode is that from which the electricity proceeds, and is termed the *anode;* the negative pole, or that which receives the electricity, is termed the *cathode.* Thus, when the two extreme plates of a battery are brought into direct metallic communication, the zinc plate is the positive pole, or anode, because it is considered as the source from which the electricity proceeds through the fluid to the negative copper plate or cathode. But when the wire connecting the two plates is broken, and its ends immersed in a fluid, in that case the end of the wire connected with the copper plate becomes the anode or positive pole, and the end of the other wire the cathode or negative pole, because the electric current, considered with reference to the fluid interposed at the breach of the wires, now proceeds from the copper, and passes back to the zinc. The fluid, such as sulphate of copper, which undergoes decomposition, by the electric current passing through it, is termed the *electrolyte;* the action is termed *electrolysis.* When this action occurs, the metal is deposited upon the cathode or negative plate, and the oxygen is liberated at the anode or positive plate, which is dissolved in the fluid. Numerous equivalent terms have been invented, with which it is perhaps unnecessary to perplex the reader.

DISCOVERY OF ELECTRO-METALLURGY.—It has been stated that Professor DANIELL, in using his constant battery, observed the deposition of metallic copper upon the negative surface; and, subsequently, De La Rue, experimenting with the same form of battery, not only found the copper plate covered with a coating of metallic copper, but further observed that the sheet of copper thus formed, having been stripped off, exhibited the counterparts of every scratch of the plate on which it had been deposited. Nay, it has been remarked that, even so early as in 1805, Brugnatelli had gilt silver medals by a similar process.

Still, the idea of applying these observations and experiments to any practical purpose, did not occur to any one in this country, so as to be publicly claimed as a new discovery, till a paragraph appeared in the *Athenæum* of 4th May, 1839, announcing that Professor Jacobi, of St. Petersburg, had discovered a method of converting any line, however fine, engraved on copper into a relief, by a galvanic process. In consequence of this announcement, Mr. Thomas Spencer, who had been privately engaged in prosecuting the same subject, gave notice to the Liverpool Polytechnic Institution, on the 8th of the same month, that he would make a communication of a process which he had discovered for effecting results similar to those of Professor Jacobi. He afterwards changed his mind, with the view of reading his paper at the approaching meeting of the British Association, to which it was communicated for that purpose; but having been overlooked by Dr. Lardner, it was omitted at the British Association, and was read for the first time at the next meeting of the Liverpool Polytechnic Institution on the 13th of September, 1839. The paper contained a minute account of experiments connected with this subject, in which Mr. Spencer stated he had been engaged from September, 1837. It appeared that, at that period, he had been induced to make some electro-chemical experiments with a constant battery of one cell, in which, instead of a copper vessel, a small piece of copper was used for the negative plate, and an equal-sized piece of zinc for the positive, the whole being placed in a glass vessel. In the course of these experiments, a piece of melted sealing-wax was accidentally dropped upon the copper plate, and having occasion to examine the plate during the progress of the experiment, he found that the whole of it was covered with deposited metallic copper, *with the exception of that portion which had been covered with the wax.* This suggested to him the idea that, by coating a copper plate with soft cement, consisting of bees'-wax and other materials, and drawing any letters or figures through this coating, so as to expose the copper at the parts required, the lines would be deposited in relief, and a kind of stereotype plate formed, from which impressions might be taken by the common process of printing. Mr. Spencer's efforts in electrotyping were chiefly directed towards this result, in which he succeeded beyond his expectations.

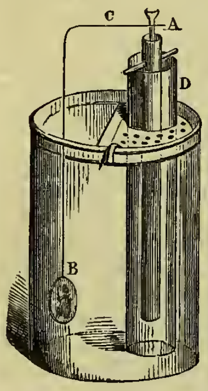
In the course of the same experiments, he afterwards hit upon the process of copying coins and medals, which, however, he considered of minor importance. This discovery he made by another accidental circumstance. When about to put the battery in operation, not having a slip of copper at hand to form the negative plate, he used, as a good substitute, a penny, which he fastened to one end of the wire, and put the other in connection with a piece of zinc. The result was, that the copper coin became covered with a deposition of copper, and in removing the wire to use it for another experiment, he pulled off a piece of the deposited copper along with it, on examining the under portion of which he found it to contain, *in intaglio*, a part of the head and letters of the coin, as smooth and sharp in every respect as the original on which it was deposited. This led him to further inquiries, and by taking impressions of coins, medals, type, and even woodcuts in sheet-lead, he finally succeeded in producing, by deposition in the battery, perfect fac-similes of them in copper, being, of course, in relief.

It so happened, that before the paper containing these details was read to the Liverpool Institution, and only a few weeks after Mr. Spencer had first given notice of his intention to read it, a letter from Mr. C. J. Jordan, a book-printer, dated 22nd May, 1839, appeared in the *London Mechanics' Magazine*, published on the 8th June following. In this letter, Mr. Jordan states that the perusal of the notice relative to a discovery of Professor Jacobi—which had been republished in the *Mechanics' Magazine*—recalled to his recollection some experiments performed by him about the commencement of the preceding summer—1838—with the view of obtaining impressions from engraved copper plates by the aid of galvanism. He then proceeded to describe his apparatus, which was a constant battery on Daniell's principle, and stated that, in making experiments with it, he remarked, on removing the deposited copper, that the surface in contact with the plate equalled the latter in smoothness and polish, from which it occurred to him, that if the surface of the plate was engraved, an impression might be obtained from it. This, he added, was found to be the case; for, on detaching the precipitated metal, the most delicate and superficial markings, from the fine particles of powder used in polishing, to the deeper touches of a needle or graver, exhibited their correspondent impressions in relief with great fidelity. Mr. Jordan proceeded in his letter to throw out some suggestions—which have been subsequently acted on with great success—for taking fac-similes by this process, of coins, medals, and other articles.

Process of Electrotype.—The art of electro-metallurgy may be considered as divided into two branches, the first and simpler of which consists in the arts of plating and gilding, or the mere deposition of metals on metallic or conducting substances; the second, or the art of electrotype, properly so called, consists in copying coins, medals, or other productions of art by electro-chemical agency. The second process, though the least important in a manufacturing or industrial view, is the more complex, as requiring the formation of moulds; but as it is the branch which is usually cultivated by the amateur, and which will allow of a complete exposition of the process with a battery of a single cell, it may be desirable to begin the elucidation of the practical details of the subject with this department.

The galvanic combination employed for this purpose is generally either a Daniell's or a Smee's battery. The former may be taken to illustrate, within small compass, the general details of the process. Let it be assumed, therefore, that Fig. 434 is a battery on this principle, differing, however, from Daniell's original construction in this, that the outer vessel, E, is of glass or earthenware, and that B, the medal or mould to be copied, performs the part of the negative plate, instead of the copper vessel described in the original form of the battery—page 788. E is charged with a nearly saturated solution of sulphate of copper; D is the porous vessel of baked porcelain, or any other porous material, filled with dilute sulphuric acid to the level of the copper solution in the jar, E. A copper wire, C, to one end of which is attached the medal or mould, B, is fixed at the other to the rod of amalgamated zinc, A. The zinc rod is inserted in the porous vessel, so as to rest upon its rim by a wooden pin passed through it, as shown in the figure, and the copper wire, C, is bent, so that the coin or medal is suspended in the sulphate of copper in the outer vessel. To keep the fluid saturated, or nearly so, some crystals of the cupreous salt are placed on the colander or perforated shelf, near the top of the jar.

Fig. 434.



When this arrangement has been made, the action immediately commences, and assuming B to be a medal or coin, or a mould of some conducting material, a coating of metallic copper is soon deposited upon it.

Such is a general plan of the very simple arrangement adopted in this beautiful process, and if it were merely the object to cover the medal or mould, B, with a coating of metallic copper, this arrangement would be quite sufficient. It is obvious, however, that on removing the metallic deposit, the impression will be found reversed, and that, to procure an exact copy or fac-simile of a coin or medal, or any other work of art, a mould must be taken on which to precipitate the metal. In the copying process, therefore, the material and formation of the moulds, and other points of importance, require attention in the first place.

Preparation of Moulds.—In the early stages of the art of electrotype, the deposition of the metals could only be effected on metallic substances, and therefore there were only two processes which could be successfully employed in the preparation of moulds —either the formation of a mould by deposition on the model, employing the electrotype process itself for this purpose, or by taking the impression of the model on a soft metal, or a metal in a state of semi-fusion, and using this for a mould. In the rapid progress of the art, however, different ingenious plans have been suggested, by which the surfaces of non-metallic substances can be so prepared as to receive a metallic deposit by the electrotype process.

By Deposition.—Assuming that the object of which a fac-simile is required, is a coin or medal, which is one of the simplest cases, the metal is deposited upon it in the manner already described, and this metallic deposit, when removed, will obviously serve the purpose of a mould, on which, by a mere repetition of the same process, a perfect fac-simile of the model may be deposited. In both processes, however, certain precautions must be taken to insure, in the first place, a good deposition of the copper only upon one surface of the medal or mould, and, secondly, to secure the means of removing the deposited coating. The method of accomplishing these objects is very simple. In the first place, a fine copper wire is wound, at one end, round the edge of the medal, and fastened by twisting, so as to secure it firmly as in a ring; the back of the medal is then covered with a coating of wax or gutta percha, which must be carried over the edges, and a little way up the wire, but so as to leave the face of the medal quite clear; this insures the deposition of the copper only on that part of the medal which is to be copied. If the deposit were allowed to form on the back, it would be impossible to remove it without using the file. But even when confined to the face of the medal, another precaution must be taken to render it easy of removal. For this purpose, the exposed part of the medal, after being well cleaned, must be moistened with sweet oil, and then rubbed with a bit of silk till it has the appearance of being dry; or, without using the oil at all, it may be brushed over with black-lead until it acquires a bronze appearance. The other end of the wire is then attached to the zinc, and the medal is suspended in the copper solution with its face to the zinc, at the distance of an inch or less from the porous vessel. Deposition will immediately commence, and if the whole is in good working order, a coating of sufficient thickness will be formed in twenty-four hours. This may then be separated from the medal without difficulty; and by adopting the same precautions, it may be employed as a mould for successively receiving, by deposition, any number of fac-similes of the original.

Moulds in fusible metal.—It has been stated that Mr. Spencer, in his early experiments, employed lead in its solid and natural state to receive the impressions of types and other objects which he intended to copy by the electrotype process. It is evident, however, that moulds taken in this manner must have been very imperfect, besides being limited in their application on account of the pressure required. The only metallic moulds now formed by impression are in fusible metal—a term applied to alloys of two or more metals, which, in combination, melt at very low temperatures. Mr. Napier, in his excellent work on Electro-metallurgy, gives the following as examples of compositions which are found to be suitable for this purpose:—

Tin.	Lead.	Bismuth.	Zinc.
1	1	2	0
1	2	3	0
1	0	1	1

Any of these compositions melt at a temperature below boiling water. To prepare them, the ingredients are fused together in an iron ladle, poured out, broken up, and remelted two or three times, so as to secure their intimate mixture with each other. The medal or coin to be copied is brushed over with a little sweet oil, using a very soft brush, and taking care to brush the oil well into all parts of the surface, which is then wiped with a piece of cotton wool. The edge of the medal is then bound round with a slip of tin or card, so that the edge of the slip may rise about a quarter of an inch above the most prominent part of the face of the medal. The alloy, in a state of fusion, is now poured into a saucer or small wooden tray, and when it begins to *set*, or has cooled down into a semi-solid mass, the operator brings the medal suddenly upon it, face downwards. When cold, the slip around the medal is removed, and the mould is easily separated. This mould is used in the same way, and with the same precautions, as the preceding.

Non-metallic Moulds.—As the metals are deposited from their salts, by galvanic action, only on conducting substances, the electrotype, as already stated, was limited in its first stages to deposition on metals. This was a barrier to its useful application for many important purposes. Moulds from non-metallic objects could not be taken by deposition, and moulds formed by impression could not be taken in the substances best adapted for such uses. This difficulty was first overcome by Mr. ROBERT MURRAY, who found that metallic deposition was effected even on non-conducting substances, by previously rubbing them over with the substance known as plumbago, graphite, or black-lead. This discovery, simple as it seems, immediately rendered the electrotype almost universal in its applications. It opened up a wide field for its cultivation, struck down the only bar to its progress, and no greater boon could have been conferred on the cultivators of this delightful art. Casts in plaster of Paris, figures or mouldings in wax, engravings in wood or any other material—even the innumerable graceful forms of natural objects, could now be represented and reproduced with facility in all the durability and brilliance of even the most precious metals.

In speaking of this application of plumbago, SMEE remarks that as a discovery it is fully equal in value to that of the electrotype itself. Its highest recommendation is its simplicity. The first use of it was made by Mr. MURRAY, in January, 1840; but notwithstanding its importance, that gentleman took no measures to secure even the credit of the discovery. With characteristic modesty, he only announced it orally at one of the conversaziones of the Royal Institution, and not by any written communication.

With the use of this valuable adjunct to the electrotype process, moulds may be formed of any suitable ductile, plastic, or easily fused material.

Bees'-wax, gutta percha, plaster of Paris, or compositions of bees'-wax with stearine, rosin, or other substances, in certain proportions, may now be successfully employed for that purpose. Bees'-wax, with or without stearine, is prepared for moulds by melting it over a slow fire, then stirring into it a little white-lead—about one ounce to the pound of wax—and afterwards remelting the mixture two or three times. The medal is prepared in the same manner as for moulds of fusible metal, and having been encircled with the slip of card, the melted wax is poured upon it, not too hot. Moulds of plaster of Paris are prepared with the finest material, mixed with sufficient water to give it, when well stirred, the consistence of thick cream. A small portion of this is first poured upon the face of the medal, prepared as in the preceding cases, and carefully brushed into every part of the surface to prevent the formation of air-bubbles, after which the rest is poured on till it rises to the edge of the circular rim. In an hour it will sufficiently consolidate to be removed with safety. It is then to be thoroughly dried at the fire, and afterwards saturated with wax at the impressed surface, when, on receiving a coating of plumbago, the mould will be ready for use. But except when very large moulds are required, plaster being found inferior to wax, is rarely employed for the purpose.

One of the best materials for moulding is gutta percha. In using this substance, it is heated in boiling water till quite soft; the medal is surrounded with a metallic rim, or placed with its back down in a saucer of the same form; the gutta percha is pressed upon the medal till it stands above the edge of the rim; additional pressure is then applied by a common copying press, and continued till the gutta percha is quite cold. Mr. NAPIER states that, when sufficient force is applied, the impressions taken in this way are generally very fine; and gutta percha possesses the advantage of readily taking on the plumbago.

Mr. GORE recommends, as an excellent composition for moulds, a mixture consisting of two parts of gutta percha and one part of Jeffrey's marine glue. The latter, in small pieces, is melted at a gentle heat in an iron ladle; the gutta percha, also in minute fragments, is then added, and the whole stirred until thoroughly incorporated. This substance, says Mr. GORE, presents several important advantages over gutta percha alone as a moulding material; it is softer when heated, and takes a much sharper impression; it contracts more in cooling, and may therefore be more easily removed from the original; in taking the black-lead it is most excellent, far superior to gutta percha; and with ordinary care many copies in copper may be taken from it by deposition.

Wax moulds are sometimes taken from medallions or other articles composed of plaster of Paris; or, by brushing the face of the model with plumbago, copper moulds may be deposited upon them by the usual electrotype process. In both cases the plaster of Paris must be saturated with boiled linseed oil, and then laid aside to dry, when the plaster will assume the appearance of polished marble. Moulds of plaster, or in fusible metal, may be taken in a similar manner from plaster models; but in these cases, to prevent adhesion, the latter must be saturated with a mixture of soap and tallow, prepared by boiling in water over a clear fire, and used by potters under the name of *lacquer*.

Elastic Moulds.—It is evident that all the preceding preparations can only be applied to the taking of moulds from such objects as coins, medals, medallions, or figures, of which one side only is to be copied at one operation. It is true, that by taking the different sides successively, and afterwards joining the different pieces together, a perfect fac-simile of many objects may thus be formed in deposited metal by the electrotype process, but still an effective method was wanting of taking a mould of any kind of model, such as a bust or statuette, or the infinite variety of natural objects, in one piece. This has been ingeniously effected by using moulds of an elastic material, as patented by Mr. Parkes of Birmingham. The composition which he uses for this purpose is similar to that employed by letterpress printers for their inking-rollers, and consists of a mixture of glue and treacle, in the proportion of four pounds of the former to one of the latter. The glue is steeped for several hours in as much water as will moisten it thoroughly; it is then put into a metallic vessel, which is placed in a bath of boiling water. When the glue becomes fluid, the treacle is added, and the whole is well mixed by stirring. The object from which a mould is to be taken is then introduced into a cylindrical vessel of sufficient depth to allow the object to be more than covered by the composition when it is poured into the vessel. The object must be weighted, or otherwise fixed down to prevent it from floating; and if it be a small plaster bust, for example, this may be effected by filling its interior with sand, and then covering the hole at bottom with a piece of paper, which must be pasted on to prevent the composition from entering. The vessel is then oiled in the inside; the bust also is drenched in oil, and placed upright in the vessel. The composition is now poured in, till the figure is covered to the depth of an inch. The whole must stand till perfectly cool throughout, after which it is taken out by inverting the vessel upon a table. The mould is then to be cut up the back and round to the front of the head with a sharp knife, when it is carefully held open until an assistant lifts out the bust. It is then allowed to re-close, and tied round with a piece of brown paper to keep it firm, but at the same time in such a manner that no distortion may be produced.

The interior is now a perfect mould of the bust or other object; but it is composed of a soluble material, and therefore cannot be inserted in any electrolytic solution to receive a metallic deposit. It furnishes the means, however, of preparing in materials suitable for that purpose any number of casts or fac-similes of the model. The composition generally used for this purpose is a mixture of wax and rosin, with occasionally a little suet, stearine, or, by preference, deer's fat, if procurable. This mixture is melted, and having been allowed to stand till it just retains its fluidity, is carefully poured into the mould, and left to cool. If too hot when introduced, it would melt the mould. The object to be kept in view, therefore, in preparing the mixture, is to compose it of ingredients which will produce a composition, not only capable of taking a good cast, but retaining its fluidity at such a temperature that it may be poured into the mould without injuring it.

A perfect wax model of the bust or other figure is thus formed, and may be extracted from the mould in the same manner as the original model. Any number of successive casts may be taken by the same process, so long as the mould remains uninjured; and these, being covered with plumbago, or prepared by a patent process to be afterwards mentioned, may be employed to receive a copper deposit. When this deposit is sufficiently thick, the wax may be melted out, or the figure, with its copper deposit, may be sawn into two pieces, the wax figure abstracted, and the two halves of the copper readjusted together. In either case the operator is furnished with a copper mould, the interior of which may be cleaned and prepared, by washing with alcohol and acids, for receiving a deposit of one of the precious metals. A perfect fac-simile of the model is thus obtained in silver or gold, and the copper is dissolved off by acids which do not attack these metals.

Moulds of figures in plaster of Paris may be taken in copper by deposition in the same manner. The figure is first saturated with wax, then covered with any conducting substance; and copper deposited upon it of sufficient thickness to bear handling. In this case the figure, with its copper deposit, must be sawn in two, and the plaster separated by boiling. When a copper mould is thus obtained, it may be prepared to receive an interior deposit of copper or any other metal, if of copper or of any metal that yields to the same acids, the mould is removed by being peeled off.

Preparation of Non-metallic Objects to Receive Deposit.—The use of graphite or plumbago for this purpose, and its first application by Mr. Murray, have been already noticed; but other substances have also been employed to give to the surface of the model or mould the requisite conducting properties.

Plumbago is generally used for small articles, such as medallions, or any non-metallic objects to which it can be applied with facility. It is laid on that part of the surface on which the deposit is required, with a hare's foot or soft brush. The surface of the object should be occasionally breathed upon to facilitate its adhesion, and any excess of the graphite blown off. The brushing must be continued until all the face, round to the wire or slip of copper forming the connections, has acquired a complete metallic lustre. Care must be taken to bring it into contact with the connecting wire, otherwise no deposit will be obtained. At the same time, in the case of a medallion, for example, it must not be carried round upon any part of the back, which would cause the object to be partially encased in the deposit, and the latter would be difficult of removal.

Mr. Gore remarks that there is the greatest difference between different specimens of black-lead in their value for this purpose—some causing the deposit to spread all over very quickly, whilst others scarcely cause it to spread at all. He recommends as the best he has found, and as possessing excellent qualities, Dix's black-lead, which is sold in twopenny packets, and one of which will last a long time for amateur use.

When the object is large, complex, or much undercut, Mr. Parkes' patent process is generally used for imparting a conducting power to its surface. This is effected by covering the object with a film of gold or silver in the following manner:—Sixty-four grains of wax or tallow are melted, then eight grains of finely cut caoutchouc are dissolved in one hundred and sixty grains of bisulphide of carbon, to which the melted wax or tallow is added, and the mixture well shaken; sixty-four grains of phosphorus are now dissolved in nine hundred and sixty grains of the same solvent, and the resulting solution thoroughly mixed with the previous one. The silvering liquid is made by dissolving eighteen and a quarter grains of pure metal, in about twenty grains of nitric acid, and diluting with twenty ounces of distilled water. The gilding liquid is made by dissolving five and a half grains of pure gold in about twenty-two grains of aqua-regia, and diluting with twenty ounces of distilled water.

The model or mould, after the connecting wire and a number of fine guiding wires directed into all the hollow and distant parts of its surface, have been joined to it, and its exterior perfectly dry, is dipped into the phosphorus solution for one minute, and after being drained is allowed to dry for half an hour or forty minutes. When dry it is immersed in the argentiferous solution for one or two minutes, until it appears like black china, when it is washed by pouring distilled water gently over it. The mould is then treated in a similar way with the gold solution, which gives it a yellowish bronze appearance, and after being washed it is ready to be coated.

This process is chiefly applied when a permanent coating of gold, silver, or any other metal is to be deposited upon the model. It may, however, be employed with advantage, in connection with the elastic mould, to deposit a mould of copper on the wax models formed by that process. The solutions of silver and gold, prepared as above, will last for a long time, and will serve for many operations. Either may be used separately with good effect, but the best results are obtained by dipping the object from which a mould is to be taken, in both solutions.

Surfaces of glass, says Mr. GORE, may also be prepared for receiving deposits by means of the phosphorus, silver and gold liquids, but not with very satisfactory results. He has adopted a much better method of preparing such surfaces by making use of DRAYTON and THOMPSON'S patent process for silvering glass, which, when well executed, effects the object admirably; the deposit, whether of silver or copper, spreads instantaneously upon it, and the contact of the deposit with the glass is exceedingly close and perfect. It is done as follows: Take one part by weight of liquid ammonia, two parts of nitrate of silver, three parts of distilled water, and three parts of alcohol; dissolve the nitrate of silver in the water, add the ammonia, and shake them well, then add the alcohol and shake again, and allow it to settle until it is quite clear; pour off the clear liquid into the glass vessel to be silvered, which must be perfectly clean; then add to the clear liquid one quarter of a part of grape-sugar dissolved in weak spirit of wine and mix, and finally heat the liquid to about 150° or 160° Fahr., and in about twenty or thirty minutes the glass vessel will become silvered. The liquid may then be thrown away, the vessel gently rinsed with distilled water, the connection carefully made with the silver coating and the battery, and the deposit formed upon it in the ordinary way.

If a strongly adherent deposit is required upon glass or porcelain, the only plan to be pursued is to send the articles to a glass and porcelain gilder, and have gold-leaf burnt into their surfaces; a deposit, either of silver or copper, may then be easily made upon them by the battery process, and will be perfectly adherent.

DIFFERENT BATTERY ARRANGEMENTS.—Having explained in the preceding pages the general principles of the electrotype process, the methods of making various kinds of moulds, and of preparing non-metallic objects to receive a metallic deposit, the Editor will now proceed to describe the different arrangements of battery employed, and the practical details of the operations.

Single Cell Process.—This is the simplest arrangement, and has been already explained in general terms —page 794—with a view to illustrate the principles on which the electrotype acts. By reference to the figure which accompanies that explanation, it will be observed that in this arrangement the battery itself is employed to receive the object to be coated, or from which a mould is to be taken, and that the entire apparatus consists of a single cell of a Daniell battery, the principles of which were explained at page 788. It is manifest, indeed, that no other form of battery can be applied in this arrangement, because it is the only battery in which a metallic solution is employed. The mere operation of this battery is, therefore, in itself a good illustration of the electrotype process; the solution yields the metallic deposit, and the medal or other object intended to receive the deposit acts as the negative plate of the battery.

The single cell process is, however, only employed in operations on a small scale, and is, therefore, chiefly confined to amateurs. It furnishes a small, compact, and very convenient apparatus for such operations. A common glass tumbler or preserve jar may be employed for the outer vessel to hold the sulphate solution; for the porous tube, to contain the dilute acid, biscuit porcelain is the best material, and is formed in the shape of a narrow cylindrical vessel, which may be inserted in the tumbler or jar, leaving about an inch between them all round. A common lamp-glass, closed at the bottom with plaster of Paris, or with a piece of skin or bladder tied firmly round it, will serve the purpose sufficiently when nothing better is at hand. DANIELL employed the gullet of an ox for his porous vessel in his first experiments. Common unglazed garden pots, with the aperture at bottom closed by a cork, are found to be well adapted for the purpose, and may be employed with great advantage when the outer vessel is sufficiently large to contain them. The form of the vessel is unimportant. It may be a trough divided by a porous partition consisting of thin sycamore wood, plaster of Paris, or any other suitable material; but biscuit porcelain is the best.

Fig. 435.

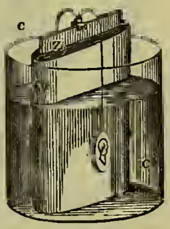


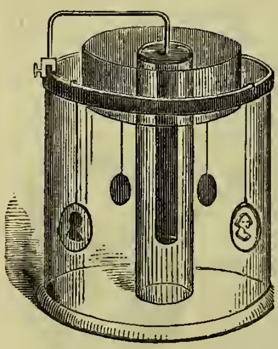
Fig. 435 represents an excellent form of apparatus for the single cell process. It consists of a large preserve jar or glass tumbler, C C, and a flat porous vessel, V, about half an inch thick, four inches in depth, and three to three and a half inches broad, inside measure. Place in the porous vessel a piece of amalgamated zinc, Z, of such a size as will fit easily, and stand an inch above the mouth of the cell. When the outer vessel is filled with a solution of sulphate of copper, a series of medals may be put in on both sides of the porous cell, and the wires attached to the zinc plate.

The only fluids hitherto mentioned as employed in the single cell process have been sulphate of copper and dilute sulphuric acid—the former in the outer vessel containing the object to be coated, and the latter, which is termed the exciting solution, in the porous tube. But instead of the sulphuric acid, a solution of chloride of sodium, or sulphate of zinc, or chloride of ammonium, may be used with excellent results as the exciting fluid. In the batteries for working the French telegraphs, nothing but pure water is put into the porous cell. The water, indeed, is the real agent in oxidizing the zinc, and thereby exciting the action, but its conducting powers are improved, and the film of oxide which forms on the zinc is more rapidly dissolved off, by mixing with the water a little sulphuric or hydrochloric acid, or one or other of the salts above-mentioned. When sulphuric acid is used, the proportions which have been found by experience to be the best are twenty-four parts of water to one of acid.

For the other solution, the sulphate of copper—*blue vitriol* of commerce—is the salt uniformly employed when copper is the metal to be deposited. For preparing the solutions of other metals, instructions will be given in a future page, in treating of the separate battery process. To prepare the cupreous solution, dissolve in a quantity of cold water as much of the copper salt as it will take up; allow it to stand till quite clear, and then add about one-fourth more water. A new solution is improved by the addition of a few drops of sulphuric acid, or a little sulphate of zinc. When the battery is in operation, let some crystals of the sulphate be placed on a perforated shelf, or suspended in a bag near the surface of the fluid, not to bring it to a state of saturation, which is not desirable, but to maintain the original strength of the solution.

By carefully attending to these precautions, the simple apparatus of the single cell may be applied with the best results for operations on a small scale; and by connecting with the zinc rod or plate a sufficient number of copper wires, any corresponding number of medals or other objects may be suspended in the cupreous liquid. This is very conveniently effected by the apparatus represented in Fig. 436, which shows the zinc connected by a wire and binding screw with a metal rim; and from the latter can be hung several moulds, all of which will thus be in metallic connection with the zinc rod. The process succeeds better, indeed, when several moulds are thus operated upon at once than when only one is introduced.

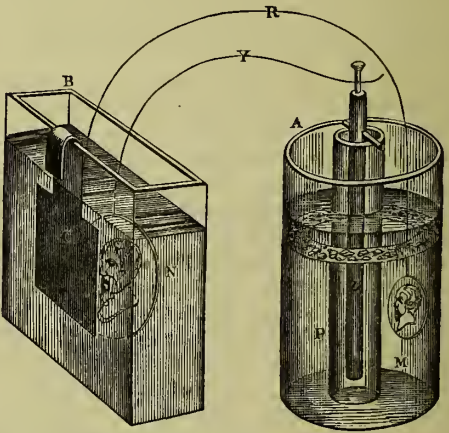
Fig. 436.



SEPARATE BATTERY PROCESS.—As the application of plumbago to impart a conducting power to the surface of non-metallic bodies was the first important step in the progress of electro-metallurgy, so it may be said that the second was the use of a separate or detached battery to work the chemical machinery of the process. Mr. MASON and Professor JACOBI had the honor of suggesting the second improvement, which is now almost universally applied in electro-metallurgical operations on the large scale. The battery being in a separate vessel from that in which the articles are placed to receive their metallic deposit, may thus be adjusted to any required power; the vessels or vats, in which the deposition is performed, may be made of any capacity; their fluid contents may be changed or renewed, and the articles immersed in the solution or withdrawn, after receiving the deposit, without interfering with the steady working of the battery; the latter may also be replenished or replaced, either in whole or in part, without interfering with the articles immersed; and lastly, a battery of any intensity or any convenient form may be used, whereas, in the single cell process, the choice is limited to DANIELL'S, and the power, as its name expresses, to a single pair.

The separate battery, as first suggested by MASON, was, however, a combination of the single cell process above described, with the use of a separate vessel, to which the electric current was conducted from the medal or other object suspended in the battery. This arrangement is shown in Fig. 437, where it will be seen that one part of the apparatus consists of a single cell, A, of a DANIELL'S battery with its porous tube, P; but that the medal, N, connected with the zinc rod by the wire, Y, is suspended in a separate vessel, B. This vessel, like the jar of the battery, contains a solution of sulphate of copper, and a plate of copper, C, is suspended within it, opposite and parallel to the medal, N. Another wire, R, connects the plate C with the medal, M, in the jar, A. By this arrangement, the electric current proceeds from the zinc, Z, through the porous vessel and the fluid media, to the medal, M, from which it passes by the wire, R, to the plate of copper, C; from this, through the sulphate solution in the vessel, B, to the medal, N, and back by the wire, Y, to the zinc rod, so that, as regards the medal, M, the action is precisely the same in principle, though not in degree, as if the wire, R, by which that medal is suspended, were a

Fig. 437.



mere continuation of the wire, Y, or were itself directly connected with the zinc rod. The action is not the same in degree, for the current, in passing from R to Y, through the cupreous solution in the vessel, B, encounters greater resistance than if it were transmitted directly by a wire from the medal, M, to the zinc rod. To compensate, however, for the slower action, additional duty is performed; for the current, in passing from C to N, decomposes the solution in the vessel, B; and while M is receiving a deposit in A, the medal or any other object, N, in the other vessel, B, is receiving an equivalent deposit at the same time.

It is worthy of remark that, by this arrangement, no crystals of the sulphate require to be suspended in B; for while, by the galvanic action, the copper from the solution in that vessel is transferred to the mould, the copper sheet is at the same time dissolved by the liberated sulphuric acid, with which it is converted into sulphate of copper, thus keeping up the strength of the solution without the addition of crystals of that salt.

In this case, also, the electricity, having to pass through a second solution, is made to perform double duty. For each ounce of zinc dissolved, two ounces of copper are deposited, and therefore, when time is of no importance, this arrangement is more economical than by the single cell. The additional resistance encountered by the current, however, in passing from C to N, requires about double the time for the operation. Mr. Napier found that, while the mould in a single cell apparatus had gained 100 grains, and the zinc plate lost 108 grains, the moulds in the two cells of Mr. Mason's arrangement had, in the same circumstances, and during the same time, received an aggregate deposit of 60 grains for 35 zinc dissolved. But,

60 : 35 :: 100 : 58·3.

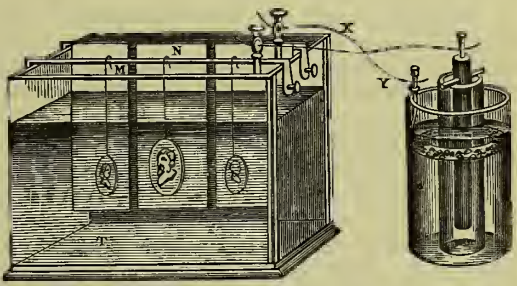
By the latter arrangement, therefore, not quite 60 grains of zinc—instead of 108 by the single cell—would have been required for the deposit of 100 grains of copper; but the loss of time would have been nearly double—a circumstance often of little importance, indeed, in conducting an operation that does not require constant attention.

From Mason's combination of the single cell apparatus with a separate decomposition vessel, one step only required to be taken to bring the apparatus to the form in which it is now most commonly used in electro-metallurgical operations on the large scale. This improvement was soon made, and consisted in using the battery simply to generate the current, and confining entirely to a separate vessel the objects intended to receive the metallic deposit. This arrangement has some important advantages. The galvanic battery and precipitating trough, says Smee, is the process almost universally adopted for all large objects, and there are many reasons why it should be employed. In the first place, one is enabled to regulate the quantity of electricity to the strength of the solution far better than by any other method; secondly, to keep up nearly a uniform strength of solution; and lastly, the process is frequently cheaper. To these the further advantage may be added, that any suitable description of battery may be used, instead of the operator being limited to Daniell's, as with the single cell, and that it is sometimes found convenient, in electro-metallurgical establishments, to have the batteries in one room and the troughs in another, the connections between them being formed by thick wires or ribands of copper carried through the intervening partitions.

This arrangement is exactly the same in principle as that illustrated by Fig. 412, p. 783, where the wire which connects the two plates is supposed to be broken, and its ends, at the point of fracture, introduced into the fluid contained in the vessel, B. In that case, the current which formerly proceeded from the copper, C, to the zinc, Z, through the unbroken wire, is simply continued through the fluid in A, which now forms a part of its course, but offers much greater resistance than if the metallic communication were uninterrupted. The degree of resistance will vary with the nature of the fluid, and the mass or thickness of it interposed between the ends of the wires. These extremities are termed the *electrodes*, or passages by which the electricity enters the fluid at one side, and emerges from it at the other. Pure water is a bad conductor, and offers, therefore, very great resistance; but sulphate of copper and other solutions employed in electro-metallurgical processes are good liquid conductors.

This method of procedure will be better understood from the annexed engraving—Fig. 438—where B is a cell of Daniell's battery, and T the decomposition trough.

Fig. 438.

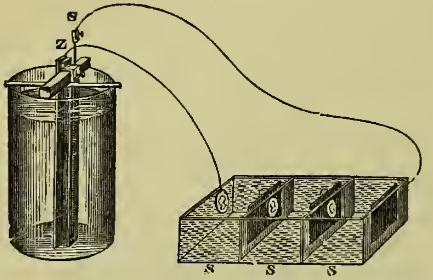


In this case, the battery is one of Daniell's original cells, having the outer vessel of copper, as described at page 788; or a cylinder or sheet of copper immersed in the outer liquid will serve the same purpose; M and N are brass rods fixed longitudinally over the trough; to the former are suspended the moulds, and to the latter sheets of copper exactly facing the moulds; the zinc of the battery is connected with the rod, N, by the wire, Y, and the copper of the battery with the rod, M, by the wire, X.

The motive power is here represented as one cell of Daniell's battery; but it is manifest that Wollaston's, or Smee's, or Grove's, all of which have been already described, may be employed in this arrangement; and one or more cells may be applied according to the power of the battery, the nature of the operation, and the amount of resistance to be overcome.

The trough may also be divided into separate cells. Thus, in the next engraving—Fig. 439—a Smee's battery is shown in connection with a trough divided by water-tight partitions into three cells, S S S. In these cells the galvanic series is made by alternating the metal to be dissolved, with the object to receive the deposit, the last mould being joined to the zinc, Z, of the battery, and the last copper with the silver, S.

Fig 439.



When this form of precipitating trough is used, the positive plates employed should be large, and the liquid rendered as conducting as possible, to lessen resistance. But even when these precautions are taken, it does not appear to possess any important advantage over the common undivided trough represented in the preceding figure. It is true that the electricity from the battery, passing through all the cells in succession, reduces its equivalent in each. Thus, the reduction of one ounce of zinc in the battery would deposit the same amount of copper multiplied by the number of cells, whereas, in the ordinary single trough, whatever be the number of moulds immersed, the reduction of one ounce of zinc will only produce a deposit of one ounce of copper on the whole. But this apparent advantage is neutralized by the additional resistance to the current, in having to pass through the fluid of each cell in succession, whereas, with the undivided trough, the current has only to pass once through an equal thickness of solution. The resistance is therefore increased in proportion to the number of cells into which the precipitating trough is divided; and the number of pairs of plates of which the battery is composed would require to be augmented in the same proportion, to give intensity sufficient to overcome this resistance. The mere increasing of the size of the plates would not effect the object; for, as was previously remarked, the intensity of voltaic electricity, or its power of overcoming resistance, depends upon the number of the pairs of plates, and not on their magnitude.

Having stated that any form of battery may be used with a separate decomposing trough, either compound or single, it becomes a matter of interest and importance to compare the relative decomposing power of different batteries. With electrodes double the size of the zinc plates, and all at equal distances, namely, one inch apart, Mr. Napier found the following results, employing only one pair of plates for each battery:—

	In one hour.
Grove's battery deposited.............	104 grains.
Single cell ,, ...	62 ,,
Daniell's ,, ...	33 ,,
Smee's ,, ...	22 ,,
Wollaston's ,, ...	18 ,,

But the same chemist observes that the first hour of the action of most batteries differs from any hour afterwards, so that one kind of battery may be most useful for a short time, and another sort if the action is to be continued for a length of time. He gives the following table as illustrating this remark, the conditions being the same as in the last experiment, or showing, in fact, the hourly results of the last experiment continued for seven successive hours:—

	1 hour.	2 hours	3 hours.	4 hours	5 hours.	6 hours	7 hours.	Total.
								grains.
Grove's battery,	104	86	66	60	54	49	45	464
Single cell, ...	62	57	54	46	39	29	24	311
Daniell's,......	33	35	34	32	32	30	31	227
Smee's,.........	22	16	14	11	12	11	10	96
Wollaston's,....	18	14	15	12	11	10	10	90

From these results it will appear that Grove's is by far the most efficient battery; but the nitrous fumes which it evolves being highly inconvenient and deleterious, it is somewhat difficult to manage, as well as expensive in the first construction. Grove's battery is therefore little used for electro-metallurgical purposes. When a separate battery is employed, which is now uniformly the case in electro-plating establishments, Smee's and Wollaston's batteries, though slower in their operation than the others, are found to be the most convenient and economical in practice.

There are various peculiar applications of coating with copper; but before giving any account of these it will be desirable to state the processes for the deposition of other metals, especially gold and silver.

Electro-Silvering.—The old mode of silver-plating, which is still practised at Sheffield to some extent, consists in taking a piece of silver of nearly the standard of purity used for coining, soldering this upon a bar of copper, and subjecting the metals thus united to the dilating process of heavy rollers. By this process, as the two metals extend equally, the silver is reduced to an exceedingly thin covering. The plated metal is then manufactured into the required shape, and different parts are soldered together. The handles, edges, and ornaments of vessels, or other objects, are made of thin silver rolled to about a square foot to the ounce, and then struck in a die, and the hollow parts filled up with an alloy of lead and tin. The dies used in these operations at some manufactories are stated to have cost many thousand pounds. This alone is a serious objection to the old method; but its principal drawback consists in the fact, that the articles can only be plated by this process *before* being manufactured into the required form, and an article so plated, when worn through in any part, was valueless before the introduction of the electro-process. There are other objections to the old method, but the heavy restrictions on taste and design which it imposes, compared with the entire freedom and facility of merely depositing the silver by electrical agency on articles already manufactured, and of any suitable metal, constitute a disadvantage so obvious that it cannot be expected to compete successfully with the new process.

It was some time before the electrotype was applied to the deposition of any metal but copper. The first practical method of depositing the noble metals with a satisfactory result was patented by the Messrs. Elkington. The solutions they employ are the argento-cyanide and auro-cyanide of potassium—the former to deposit silver, and the latter for gold.

The argento-cyanide, or silvering solution, consists of cyanide of silver dissolved in cyanide of potassium. This solution may be prepared in various ways, but it will be sufficient to indicate the two most eligible processes. One of these is performed by simple chemical mixture, and the other with the aid of a battery.

To prepare the solution by the chemical method, metallic silver is dissolved in four parts of nitric acid, diluted with one part of water; the diluted acid is heated in a vessel, and the silver added by degrees until all dissolved. A solution of nitrate of silver—lunar caustic—is thus formed, which is transferred to a large vessel, and further diluted with ten parts water. Dissolved cyanide of potassium is then added so long as a white precipitate falls. This precipitate is cyanide of silver. When it has sufficiently settled down, the clear liquor is carefully decanted, and after the precipitate has been well washed to remove the soluble salts, a solution of cyanide of potassium is added to it until it is completely dissolved. The resulting liquid constitutes the cyanide of potassium and silver, and forms the silvering menstruum, which should be diluted to such an extent as to contain one ounce of silver in the gallon. The salts of potassa *in strong solution* exercise a slightly solvent action on cyanide of silver, and it is to prevent a loss from this source that the nitrate of silver is diluted previous to adding the cyanide in the first instance.

But the best and most economical method of preparing the silver solution, and that which is generally employed in electro-metallurgical factories, is by the use of the battery. To make a depositing liquid containing one ounce of silver to the gallon by this process, make a solution of cyanide of potassium of the strength of one and a quarter ounce to the gallon of water employed; then place a porous vessel in this mixture, so as to stand with its mouth at least one inch above the surface; fill this vessel with the same liquid to the level of the liquid in the outside vessel; put into the porous cell a sheet of copper or iron, and connect it with the zinc terminal of a battery; in the bath or large solution put a sheet of silver, and connect this with the copper terminal. By the aid of a Wollaston's battery, consisting of four pair of plates, the zinc ones being about six inches square, the required quantity of silver will be dissolved in the bath in the course of a few hours, forming the cyanide of potassium and silver, which is now ready for use. By weighing the sheet of silver before and after the operation, the quantity that has been dissolved will be ascertained.

From this solution, prepared by either of these processes, silver may be deposited upon any metal; but copper, brass, and German silver, are the best for plating upon. Lead is by no means difficult to plate, but the two metals have generally a weak adhesion, because the lead, although made perfectly clean, becomes in part coated with an insoluble cyanide as soon as immersed in the solution. From its softness, also, it readily yields to the pressure of the burnisher. Tin, zinc, iron, pewter, and Britannia metal are not so easily coated with silver as lead; but all are occasionally plated by the electro-process, though the metal now most generally used for all new work is German silver.

Whatever be the nature of the metals to be plated, the articles intended for this purpose must not be immersed in the silver solution until they have been carefully prepared to receive the deposit. In plating and gilding, a principal object is to render the deposited metal as fixed and permanent as possible; but if the surface of the article has not been properly prepared, the deposit will rise up in blisters, which a touch of the burnisher will rub off, and the whole operation will be useless. The careful preparation of the articles is therefore a point of vital importance

This may be performed by the wet or the dry method. M. Becquerel prefers the latter, which, however, can only be applied when the work of the article is not of a delicate character. The object of the operation in both cases is to remove from the surface intended to receive the deposit every particle of grease and oxide, which, if present in the smallest quantity, tend to diminish the adhesion. The dry process simply consists in scouring the articles with sand, glass, or emery paper, or with very fine pumice-stone powder, using for this purpose clean brushes perfectly free from grease, or bundles of fine brass wire, technically called scratch-brushes. Particular care must be taken to avoid contact with the moisture of the hand, which both oxidizes and greases the surface. The alleged advantage of the dry over the humid process is, that in the latter case, an interval, however short, must always occur between the act of removing the article from its last liquid bath, and placing it in the solution of the metal to be deposited; and during even that momentary interval the article, or some part of it, is liable to acquire a film of oxide.

From the nature of the articles subjected to the process, the number of cases in which the dry method is available is, however, very limited. The other method is, therefore, generally practised in factories, and by the exercise of due care the adhesion may be rendered by this process quite perfect. It consists in alternately subjecting the articles to alkaline and acid solutions, the former to free them from grease, and the latter from oxide; brushing or rubbing with fine sand, and rinsing in pure water. The article is first boiled in a lie of caustic potassa or soda, containing about half a pound of the alkali to the gallon of water, and then dipped into nitric acid, diluted to such an extent as merely to act upon the metal. It is then scoured with a hard brush and sand, of which a very fine description obtained from the Isle of Wight is the best; after which it is washed thoroughly, and dried, and then weighed. A copper wire is now attached to it, either by twisting it round the article or putting it through any open part. It is then dipped into nitric acid, containing ten per cent. of sulphuric acid, or into a mixture technically termed *pickle*, and composed as follows:—

Sulphuric acid,	64 parts.
Water,	64 „
Nitric acid,	32 „
Hydrochloric acid,	1 „

It is quickly removed from this bath, washed by immersion in distilled water, and then without loss of a moment dipped in a solution of nitrate of mercury till the surface is white. From this the article is taken out and *struck* in the silver solution; that is to say, it is suspended by the wire connected with the zinc of the battery, when it is immediately coated with a thin film of silver. This operation is termed *striking*, and batteries of intensity are used for this purpose. After a few seconds, it is taken out and well brushed. On the large scale, brushes of brass wire attached to a lathe are employed, but for small operations a little fine sand rubbed with a hard hair brush will effect the object, which is to remove any particles of foreign matter that may still adhere to the surface, and to test the completeness of the coating. The article is then washed in water, and replaced in the plating solution, and in the course of a few hours a coating of the thickness of tissue paper will be deposited upon it, having the beautiful matted appearance of dead silver.

If it is desired to preserve the dead surface, the object must be taken out, and immersed in boiling distilled water for a few minutes. On being withdrawn, it will dry immediately by its own heat, and then it must be placed under a glass shade, or otherwise protected from the action of the air, which, by forming a sulphide upon it, would tarnish it in a few days.

Mr. GORE remarks that the practical minutiæ of preparing the surfaces of various metals for receiving adhesive and non-adhesive coatings of different metals and in different liquids, vary considerably in different manufactories, and much information yet remains to be acquired respecting the particular methods required for particular metals and liquids, and from a want of this knowledge the most skilful operators occasionally fail in producing complete and strong adhesion, especially in coating Britannia metal, zinc, lead, tin or steel, with silver; iron or zinc with copper, *et cetera.*

Bright Deposit.—If a bright surface is wanted, this may be obtained either by burnishing, or by the addition to the silver solution of a little sulphide of carbon, which has the singular effect of throwing down a bright deposit. This remarkable fact was discovered in the following circumstances:—Some operators at the works of Messrs. ELKINGTON and MASON were engaged in experiments upon elastic moulds, and whilst coating them with silver in the depositing vat, the deposits taking place upon the various articles in that vat were observed to present very peculiar and unusual appearances, some of them being exceedingly bright in different parts; these appearances were referred to the presence of the elastic moulds, and from the known existence of bisulphide of carbon in the moulds, experiments were tried of adding portions of that liquid to a quantity of plating solution, which finally ended in success, and a patent was taken out by Messrs. LYONS and MILLWARD, March, 23, 1847. The best method of applying the sulphide is to put one or two ounces into a large bottle, and then fill it with strong silver solution; this mixture is allowed to stand for several days, shaking it occasionally, when it will be ready for use, and a little may be added to the plating solution as required.

Collodion and sulphur, sesquichloride of sulphur, or the hyposulphite of either potassa or soda, are also used for the same purposes, but to a less extent. A solution of iodine and gutta percha in chloroform is said to be more permanent in its effect than bisulphide of carbon.

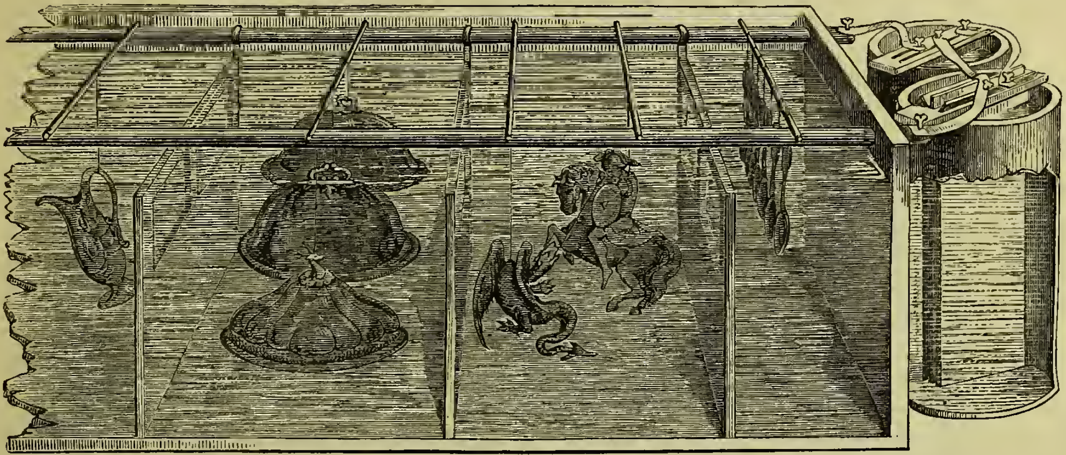
Mr. GORE remarks that a bright solution requires a large quantity and low intensity of battery-power to work it, and the anode in it is generally of a darker color than that in the ordinary liquid. It is much more difficult to operate with than the ordinary liquid; if it is not worked constantly and uniformly, it will lose its power of yielding bright metal; if any one of the articles which are being plated in it is disturbed or removed from the liquid and replaced, that one will not again receive a bright deposit, and the disturbance of the liquid by removing it will oftentimes cause all the neighboring ones to lose their brightness; or if too much brightening liquid is added, the solution will be considerably injured—indeed many silver solutions have been totally spoiled in this manner.

But the silver is generally deposited *dead*, which admits of burnishing either the whole surface, or any particular parts of it, by mechanical means. In that case, the article is first brushed over with a wire brush and old ale or beer, and then subjected to the usual process of burnishing by polishing the surface with bloodstone or bright steel.

Small articles, such as spoons, knives, forks, snuffers, *et cetera*, are generally wired before they are cleaned, that is, they have small copper wires, size number twenty or twenty-two of the Birmingham brass wire gauge, and about fifteen or eighteen inches long, twisted round them to suspend them by when in the vat, and to conduct the electricity; larger articles, such as teapots, jugs, *et cetera*, are generally wired at some advanced stage of the cleaning process after they have been scratched; and very large articles, such as fenders, hat-stands, large ornamental iron-work, *et cetera*, are not wired at all, but are suspended in the solution by strong copper or brass hooks; in cases where a very good and safe connection is required, the connecting wires are soldered to the articles.

It has been remarked, that when the article is *struck* in the silver solution, intensity batteries are used; but when afterwards immersed to receive the final deposit, batteries of volume are applied; or, in other words, batteries which furnish electricity in quantity, with greater or less intensity, according to the measure of resistance to be overcome. The power of the battery must vary according to the strength of the solution and amount of work to be done. In some of the large factories, the vats or plating vessels measure about six feet in length, by thirty inches in breadth and depth, and contain about two hundred gallons of solution, having generally one ounce of silver to the gallon. The annexed engraving—Fig. 440—is a correct representation of a silvering vat, with battery in action, as employed in the large works of Messrs. ELKINGTON of Birmingham; the manner of suspending the articles to be coated is also exhibited. The silver plates serving as electrodes are fixed upon light iron frames, which are not affected by the solution. These are attached at one corner to the rod which is connected by a copper riband with the copper terminal of the battery; the plates are entirely immersed in the solution, and partially divide the vat into compartments, as shown in the figure, so that a silver surface is exposed to each side of the articles. The latter are suspended by cross-bars, forming a metallic communication with the longitudinal rod which is connected with the zinc terminal. The batteries are those of SMEE or WOLLASTON, with plates about equal in length to the depth of the vat, and eight or nine inches in breadth.

Fig. 440.



For a vat of the capacity above-mentioned, six batteries of three pair intensity are sometimes employed, the zinc plates immersed in the acid measuring six inches by seven.

To ascertain the amount of metal deposited, it is only necessary to weigh the articles carefully before and after the operation.

When old articles are to be replated, the silver that remains upon them must be taken off before they are subjected to a repetition of the process. This may be done either by chemical or mechanical agency. To remove the silver by the chemical method, the article is placed in a stoneware or copper vessel, containing some strong sulphuric acid, to which a little nitrate of potassa is added. This solution dissolves the silver without materially affecting the copper. When the silver is completely removed, the article is well washed, then passed through the alkaline lie, and the other preparatory operations for plating. The silver is recovered from the sulphuric acid when the latter is saturated with the metal, by adding a dilute solution of chloride of sodium, which throws down the silver as a chloride; this precipitate is then collected, and the silver is obtained in a metallic state by fusing with carbonate of potassa.

The mechanical method is generally preferred, and is performed in the factories by means of a hard circular brush, fixed upon a lathe, and a thin paste made of oil and fine pumice-stone powder. By this process, if skilfully managed, the article is not only stripped of its silver, but thoroughly smoothed and polished—a necessary preparation, which old plated articles are generally found to require even when stripped by the acid process. It is therefore the preferable method to strip and polish the articles at one operation. The brushings are collected, and subjected to a red heat in an iron vessel, and that which remains after burning is fused with carbonate of soda and potassa to recover the silver.

In all cases of electro-deposition of metals, and especially in using the double cyanide solutions, the metallic deposit, which ought to be perfectly smooth, is often disfigured by vertical lines or ridges, produced by the constant upward current of the lighter parts of the solution which are set free. This is prevented by keeping the articles in motion, and different plans have been suggested for this purpose. The rods to which the articles and plates are suspended, are generally fixed into a frame, supported on four small wheels, which run upon a kind of rail formed on the edges of the vat. When steam power is at command, a gentle oscillating movement may easily be communicated to this frame; but when there is no engine, the same may be accomplished by clockwork or other devices. The superintendent of a plating establishment in Glasgow produces the motion by a bent lever, one arm of which is connected with the frame by a cord or wire, and the other carries a small pan, into which water is allowed to drop from the spigot of the pipe which supplies the vat. When a certain quantity of water accumulates, its weight overbalances the slight resistance produced by the action of the frame on the other arm of the lever; the pan, in descending, empties its contents; and the frame which, by the motion of the lever, had been drawn forward on its rail, returns to its place by the action of gravity, the rail being slightly inclined for that purpose; or if the rail is horizontal, the frame may be drawn back to its position by the action of a spiral spring, connected with the end of the vat. The retreat of the frame raises the pan, and the same operation is repeated without any care or trouble on the part of the person in charge. The simplicity of this ingenious contrivance is not the least of its recommendations. The dropping of the water is certain and constant in its action; whereas, the operation even of a steam-engine is liable to interruptions, and mechanism moved by clockwork is not only more complex, but is often brought to a stand by the simple neglect of the attendants to wind it up.

If a solution contains much free cyanide, and by any means the battery power becomes suddenly weak towards the latter part of the day, the silver deposited upon the articles will be redissolved off, because the liquid about the dissolving plates having by the day's work become saturated with metal, and that about the articles having become full of free cyanide, the two —that is, the dissolving plates and the articles—form a kind of voltaic battery, which circulates a current of electricity in an opposite direction to the original one, and thus redissolves the deposited silver. Care must be taken to guard against this accident; which, however, will not occur where motion is kept up.

ELECTRO-GILDING.—Gilding was formerly performed by amalgamation. A mixture of finely-divided gold and mercury was rubbed over the object, and the mercury afterwards driven off by heat. This process was very detrimental to the health of the workmen, as the fumes of quicksilver are extremely poisonous. It is now almost entirely superseded by the electro-process, which is, in most cases, remarkably easy, and is performed in much the same manner as electro-silvering. The metal to receive the gold may be either platinum, palladium, silver, copper, tin, or indeed almost any other metal, when the auro-cyanide of potassium is employed.

This salt is frequently made by dissolving oxide of gold in a solution of cyanide of potassium. The oxide is prepared by dissolving gold in three parts of hydrochloric acid, and one of nitric acid, which forms the chloride; this is digested with calcined magnesia, and the gold is precipitated as an oxide.

But, as with the silver solution, the best process for preparing the auro-cyanide is by the battery. This is performed by arranging a piece of pure gold as the positive pole in a solution of cyanide of potassium; a porous cell is filled with the same liquid, and then introduced into the bath; a sheet of iron or copper is now placed in the cell in such a position as to face the sheet of gold in the bulk of the solution, and both metals are connected with the battery, as described for making the silver liquid. In fact, there is no difference between the two processes, except that a sheet of gold instead of one of silver is placed in the cyanide bath, and that in preparing the gold solution, and for all the operations of gilding by this method, the liquid must be heated to at least 130° Fahr. Having made the connections, the battery is allowed to remain in action until the quantity required has been dissolved, which may be ascertained by weighing the gold electrode from time to time, and observing how much it has lost. From one half to an ounce of gold in the gallon is the common strength of the liquid used in large operations; but a weaker solution is sufficient for gilding small articles.

The articles to be gilt are cleaned in the way described for silver; but as the process of gilding is generally performed upon silver articles, the previous immersion in nitric acid is, in that case, dispensed with. When cleaned and dried they are weighed, and one immersion is given, which merely imparts a blush of gold; they are then taken out, brushed, and reimmersed. If the battery and solution are in good order, three or four minutes will suffice to gild any small article. The hotter the solution, the more rapid the operation, and the less battery power is required. If kept at 130° to 150° Fahr., three or four plates may be used; but if raised to 200°, one pair will be sufficient. A convenient mode of applying the heat is to put the jar containing the solution into a vessel of water, which is kept at the boiling point; and as the liquid evaporates by being hot, distilled water must be added after each operation, to prepare it for the following day, as it is not so good to add the water immediately before proceeding to operate. The articles, when gilt, are again weighed, and the quantity of gold deposited is thus ascertained.

Iron, tin, and lead are most frequently gilt by having a slight film of copper deposited on them immediately before being introduced into the auriferous bath. Silver articles, before they are gilt, are merely well brushed, and kept in clean water until they are immersed in the depositing fluid.

The accompanying woodcut—Fig. 441—illustrates the arrangement of the apparatus for electro-gilding as in operation at the establishment of Messrs. ELKINGTON and MASON. The battery is represented by the letters, *a a;* the *gold-vat*, containing the double cyanide of gold and potassium, is denoted by *b*. The temperature of the solution is maintained by steam circulated in a pipe coiled round the vessel between its interior and exterior sides. *d*, *d*, *d*, are baths in which the operator from time to time rinses out the objects undergoing the gilding process. At *c*, one of these is seen, which, being filled with cyanide solution, and having the gold plate —connected with the positive pole of the battery—suspended inside, merely requires the application of the negative pole for the performance of the operation. The various ribands of metal connecting the bath with the battery are seen traversing the bench.

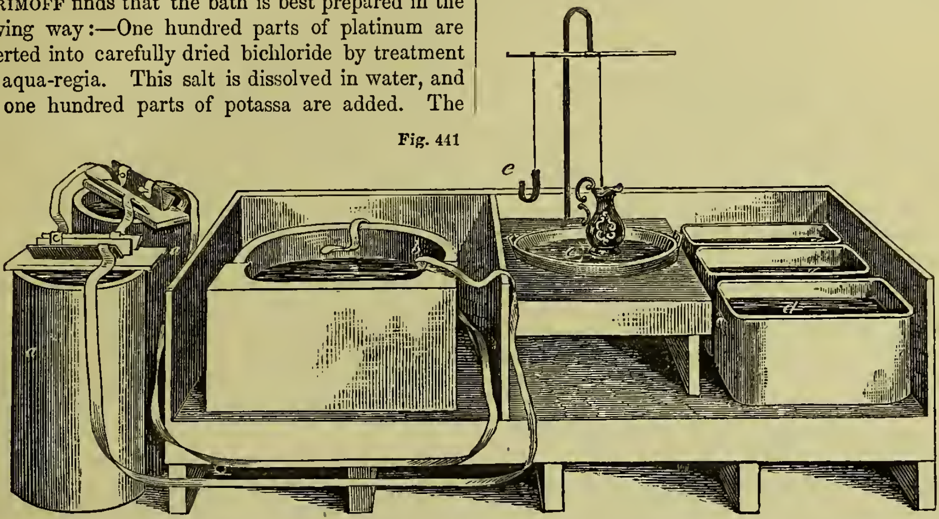
The color of the gold deposited very much depends on the strength of the battery and the temperature of the solution. By due attention to these points any desired shade may be obtained. If the battery is too strong, the hue will be black; if the battery is rather weak, and the solution too cold, the coating will be light-colored. When all the ingredients are properly regulated, the gold, on coming out of the solution, should be of a dark brownish-yellow; and this, when scratched, will yield a beautiful rich deep color.

To remove gold from articles before regilding, or when the gilding has been performed imperfectly, they may be put into strong nitric acid, to which, when the articles have been immersed, some chloride of sodium is added. This will dissolve off the gold from any metal without injuring the latter; but the mechanical method, by using the lathe-brush, as described for silver, is the best.

When the gold has been dissolved off, it may be recovered by diluting the acid, and then introducing soda or potassa till the acid is nearly neutral; after which a solution of sulphate of iron is added, so long as any precipitate falls by standing. This precipitate is then filtered; the filter with its contents is dried, and the precipitate is then fused with a little borax. Oxalic acid may be used instead of copperas with the same results. If the gold be brushed off, the washings are treated as described for silver, and fused with borax.

Electro-platinizing.—This process is similar to the preceding, but is attended with some difficulties. The depositing solution consists of the double chloride of platinum, and an alkali, which must be neutral. **Jewrimoff** finds that the bath is best prepared in the following way:—One hundred parts of platinum are converted into carefully dried bichloride by treatment with aqua-regia. This salt is dissolved in water, and then one hundred parts of potassa are added. The resulting precipitate is boiled with a solution containing seven hundred parts of oxalic acid. After this has been filtered, three hundred parts of caustic potassa are poured in. The liquid is now well adapted for electro-platinizing in the ordinary way. The object to be operated upon should be smooth, and thoroughly cleansed with an alkali before being introduced into the bath. The cathode must be of platinum, and inserted in the liquid in the manner already indicated for electro-gilding.

Fig. 441



Platinum has also been deposited from solutions of its iodide, bromide, and the double chloride of platinum and sodium. The solution of double chloride of platinum and sodium is formed by adding one equivalent—58·5 parts—of common salt to one equivalent—169·7 parts—of bichloride of platinum, and dissolving the mixture in water. The resulting solution requires a very weak battery and a small anode of platinum to obtain a reguline deposit. A deposit of platinum in the state of a black powder, for platinizing silver plates, may be very easily obtained from it by adding a little sulphuric acid to the solution, and using a much stronger battery and a larger anode.

Electro-palladiating.—For this purpose a solution is prepared by dissolving ammonio-chloride of palladium in liquid ammonia, and the compound battery process employed with a small palladium pole; or palladio-cyanide of potassium may be used for the depositing solution. To form the palladio-cyanide, dissolve some cyanide of potassium in water, immerse a large palladium anode and a small bright cathode of iron or copper in it, and connect them with a small battery of one or two pairs, and continue the action until the cathode receives a good deposit; or, which is better, put the iron cathode in a porous cell, as described for gold and silver. The resulting solution is an excellent one. This metal adheres so firmly to copper, when deposited by this process, that its removal is impossible.

Electro-coppering.—It has been seen that in depositing copper on moulds by the single cell, or the battery process, a solution of sulphate of copper is used; but this solution is not fitted for depositing copper upon iron, steel, or zinc, with a view to adherence, because the electrical relations of these metals are unsuitable to that of the copper in the sulphate, and reduce the copper upon themselves by simple immersion, in which case it does not adhere. The depositing liquid generally employed for covering iron with copper, is a solution of cupro-cyanide of potassium. It is prepared by adding to a solution of sulphate of copper a solution of cyanide of potassa, so long as there is any precipitate formed, but not more, and washing the resulting precipitate until the percolations afford no milkiness with chloride of barium. Great care must be taken not to breathe the gas evolved, which is very poisonous.

Having washed the precipitate, it is dissolved by adding a solution of cyanide of potassium, and then filtered. Four ounces sulphide of copper will make a gallon of solution. This depositing liquid must be worked at a temperature of not less than from 150° to 200°. It forms an exception to the general rule, that if the electricity be so strong as to cause an evolution of gas at the electrode, the metal will be deposited in a granular form, for this depositing liquid will afford no reguline metal unless gas be freely evolved from the surface of the article on which the deposition is taking place. This fact renders necessary the employment of batteries of some intensity. The vessels for this solution are usually of copper, and are heated over a flue, or a sand bath. They then serve as the positive electrode of the battery.

After the iron has been cleansed, an immersion of five minutes is enough to produce upon it a film of copper, but if it is desired that the iron should have a thick coating, and as the cyanide of copper process is an expensive one, it is advisable to increase the coating by means of the single cell process with a nearly saturated solution of sulphate of copper. The cupreous bath should also be made as neutral as possible, by the addition of a little caustic soda.

Electro-zincing.—The depositing liquid employed for electro-zincing is made by dissolving two pounds of sulphate of zinc in a gallon of water.

To use this solution a separate battery and a zinc positive electrode are necessary. The metal is very readily deposited; but on plumbagoed surfaces, unless great precautions are observed, the metal assumes a crystalline texture, and, therefore, is very brittle. The best way to avoid this is to use a saturated solution of the salt, and to keep the article to be coated in constant motion.

Deposition of Cadmium.—For the electro-deposition of cadmium, the following is the process described in Messrs. RUSSELL and WOOLRICH'S patent, dated March 19, 1849:—Take cadmium and dissolve it in nitric acid, diluted with five or six times its bulk of water, at a temperature of about 80° or 100° Fahr., adding the diluted acid by degrees until the metal is all dissolved. To this solution of cadmium a solution of carbonate of soda—made by dissolving one pound of the ordinary crystals of soda in one gallon of water—is to be added until the cadmium is all precipitated; and the precipitate thus obtained is to be washed four or five times with tepid water; next add as much of a solution of cyanide of potassium as will dissolve the precipitate; after which, one-tenth more of the solution of cyanide of potassium is to be added to form *free* cyanide. The strength of this resulting liquid may vary, but the patentees prefer a solution containing six troy ounces of metal to the gallon. The solution is worked at about 100° Fahr., with a plate of cadmium as an anode.

Deposition of Nickel.—Mr. GORE deposited nickel in the state of reguline white metal from a solution of the double chloride of nickel and ammonia, by making a lump of metallic nickel the anode in a strong aqueous solution of hydrochlorate of ammonia—sal ammoniac—and passing a strong current of electricity through it for several hours, as described for gold and silver, until the liquid acquired a pale greenish-blue color; also by treating a solution of one part of arseniate of potash and five parts water in a similar manner. Nickel is likewise deposited from a solution formed by dissolving the pure metal in nitric acid, then precipitating it either by a solution of caustic potassa, carbonate of potassa, or cyanide of potassium; washing the precipitate, and dissolving it in a solution of potassium, and operating by means of a battery and an anode of pure nickel. Its appearance when deposited from this solution is said to be nearly equal in whiteness to silver, and its deposition has been proposed to be applied to the production of an inferior class of plated articles.

Deposition of Iron, Tin, and Lead.—Iron and tin are easily deposited, the former from its sulphate solution, the latter from its protochloride; and lead may be deposited either from its acid or alkaline solution, but with greater difficulty. No practical value has yet been attached to the deposition of these metals.

Deposition of Antimony.—Next to copper, antimony is one of the most easy metals to deposit in a coherent state, but does not spread over black-leaded gutta percha surfaces, nor does it adhere with any degree of firmness when deposited upon copper, brass, or iron; nor has the deposition of it been yet applied to any useful purpose, although bright deposits of considerable thickness may easily be obtained. The deposited metal, also, exhibits in certain circumstances very remarkable phenomena, which render it worthy of notice. It is readily deposited from a solution of the ordinary chloride of antimony—butter of antimony—as prepared for pharmaceutical purposes, by suspending a small piece of antimony as an anode, and using a very weak battery of one or at most two pairs. The mixed chlorides of antimony and ammonia form also an excellent depositing liquid. The appearance of antimony, when deposited from any of the chloride solutions by a weak and continuous current, is very brilliant, similar to highly-polished steel. The remarkable properties to which allusion has been made, appear when it is deposited rather rapidly, and seem to have been first observed by Mr. GORE, by whom they were described in the *Philosophical Magazine* for January, 1855, in the following terms:—If during any part of the time the deposit is progressing, the deposited antimony be taken out and struck gently or rubbed with any hard substance, such as metal or glass, an explosion occurs, with a small cloud of white vapor, sometimes with a flash of light, and nearly always with considerable heat, sufficient to burn one's fingers, melt gutta-percha, burn paper, and even scorch deal wood quite brown, especially if the deposit is thick; and invariably accompanied by fracture of the deposited metal; sometimes, if the process of deposition has been interrupted, and the deposited metal is not homogeneous, only a thin scale falls off—in such cases the heat and explosion are less; in other instances, where the process was regular and the metal homogeneous, the fracture extended quite through the metal to upwards of one-eighth of an inch in depth. He observed this phenomenon in about nine instances, in several of which the explosion took place even in the liquid, by striking the deposit against the glass containing vessel; and in one instance it occurred after the metal had been well washed with dilute hydrochloric acid, dried, and had remained out of the liquid several hours.

Since publishing these observations, Mr. GORE writes in the *Pharmaceutical Journal*, that he has met with the same phenomenon many times, and in several instances a deposit has been going on in the chloride solution, and has been removed an instant for examination, and the battery power—one cell of SMEE'S—has been increased by addition of acid, and upon the next examination, some hours afterwards, the deposit has been found cracked in many directions, as if a feeble explosion had occurred in the interval, the apparatus being meanwhile unmoved. It has been suggested that the deposit is a compound of antimony and hydrogen, and this idea is favoured by the observation, that when the metal is deposited very slowly indeed the explosions do not occur, and that in every case where an explosion took place the metal had been deposited more rapidly—the extra power probably depositing hydrogen also; which, instead of being as usual evolved, might, in its nascent state, combine with the metal and form an explosive compound. Mr. GORE hazards the additional suggestion, that the metal is deposited in a peculiar structural condition—a state of unequal mechanical tension, similar to that of unannealed glass, and that when broken, the closer aggregation of the particles develops heat and light.

Another peculiarity in the deposition of antimony from the chloride is, that if the cathode be sustained, partly in the liquid, and kept uniformly at that depth without disturbance, a deposit of the metal will occur upon it at the surface of the liquid, and spread out gradually in the form of a thin button all around—if it be a wire—and ultimately touch the anode if sufficiently near, lying as a circular sheet of metal upon the surface of the liquid, whilst the deposit beneath progresses very slowly. He has a button one inch and five-eighths in diameter, and one-sixteenth of an inch thick, formed in this way upon a piece of wire three-sixteenths of an inch thick, the part of deposit beneath the surface of the liquid being only half an inch in diameter. The battery used was a one-pair SMEE'S, and the process occupied about eighteen days.

Deposition of Bismuth.—Bismuth is easily deposited from a solution formed by dissolving either the nitrate or subnitrate of the metal in a mixture of nitric acid and water. It requires a much weaker current even than antimony to deposit in a bright coherent state. Its appearance, when slowly deposited, is a very beautiful white, with a faint pinkish tint, and having a fine silky lustre.

Deposition of Brass and other alloys.—The attempts that have been made to deposit alloys from their solutions, have not been attended with much success hitherto; but a process for depositing brass, patented by MORISS and JOHNSON in 1852, is said to be productive of good results. This process is as follows:—Dissolve one pound of cyanide of potassium, one pound of commercial carbonate of ammonia, two ounces of cyanide of copper, and one ounce of cyanide of zinc, in one gallon of water; and use the solution at 150° Fahr. with a large anode of brass and a powerful battery; or a solution may be taken of one pound of cyanide of potassium and one pound of carbonate of ammonia, dissolved in one gallon of water, and saturated with copper and zinc by means of a strong battery, with large brass anode and small cathode, until the latter receives a good deposit of brass, the solution being at about 150° Fahr. To increase the proportion of copper in the deposit, either add cyanide of potassium or raise the temperature of the liquid; and to increase the proportion of zinc in it, either add carbonate of ammonia or lower the temperature. Always use a large brass anode.

Mr. GORE states that of the different solutions for depositing brass which he has tried, the above is much the best, as by it reguline and thick deposits of brass of uniform color, and of any desired composition, may be obtained.

STEELE'S mode is to dissolve separately two and one quarter pounds of American potassa, and two and a half ounces of powdered acetate of copper, previously mixed with half a pint of strong ammonia, four or five ounces of sulphate of zinc, and cyanide of potassium, two ounces; these are to be added to six gallons of warm distilled water. WALKER states that he tried this solution, but did not succeed.

The following solution of different metals is given on respectable authority as yielding a good bronze-colored deposit:—

50	parts carbonate of potassa,
2	,, chloride of copper,
4	,, sulphate of zinc,
25	,, nitrate of ammonia.

In operating with this liquid a brass plate is directed to be used as the positive electrode.

LAWS OF DEPOSIT AND PRACTICAL INSTRUCTIONS.—In coating articles with metals, it is important that the power of the battery should bear a certain proportion to the strength of the depositing liquid. The intensity of the apparatus may be raised by having a greater number of pairs, by using a less diluted acid, and by warming the electrolyte; the quantity of the electric current may be increased by lowering the zinc plates in the liquid. The opposite effects can be produced by a reversal of these conditions.

The quantity of metal deposited depends on the amount of the electric current passing through the solution, and, consequently, upon the size and number of the zinc plates in each cell of the battery, whilst its quality is regulated by the amount of the current passing compared with the size of the electrodes. The following may be given as the general laws of deposit, but different metals and different solutions vary so much that no positive relations can be fixed; only the general principles can be laid down. To obtain a bright crystalline deposit, a current of intensity and small amount is employed; for a hard and rather brittle reguline deposit, much force and moderate quantity; for a dark gritty powder, a strong and abundant stream; for an elastic and bright reguline precipitate, moderate intensity and small quantity; for a soft, tough, and perfectly reguline coating, a medium force and moderate quantity; for a soft dark powder, moderate intensity and large amount; for a soft sparkling film, low intensity and small quantity; for a tough reguline coating, low intensity and moderate quantity; and for an abundant soft black powder, low intensity and large quantity.

When the power of a battery decreases, a little acid may be added and the liquid stirred; but the better way is to substitute fresh acid. The solution in the battery should never be allowed to become thick or to crystalize. If any of the silver or copper plates of a battery, or any part of them, become covered with zinc, it is a proof that the acid is becoming exhausted.

GORE ascertained, in a long series of experiments, that the depositing power was almost invariably increased by keeping the dissolving metal hot, and the receiving article cold, by means of an appropriate apparatus. He also found that the opposite effects were produced by a *contrary* arrangement of the temperature. To insure perfect circulation of the current, care must be taken that the circuit is complete, that it is capable of conducting freely throughout, and that the various wires are perfectly clean at all their points of contact.

It may be proper to repeat here that in every case, to produce metallic deposition, there must be a complete circuit of substances: there must be a liquid in the circuit, the metal to be dissolved, and the article to be coated in that liquid, and to ascertain that this is complete, galvanometers are frequently used, particularly in cases of complicated apparatus.

Every large plating establishment has a number of stoneware pickling jars, pans, and vats of various sizes, called dipping jars, several large boilers of potassa liquid, various scratch brushes both for hand and lathe, and several washing troughs with a plentiful supply of clean water.

Mr. GORE gives the following rules for successfully working depositing liquids:—

Firstly, Avoid altering the composition or the proportion of the ingredients, except the water.

Secondly, Adapt the electric power to the liquid, that is, regulate the precipitation by alterations in the battery, rather than by any in the depositing vessel, except that the distance between the cathode and the anode may be altered, generally with advantage.

Thirdly, The dissolving metal as a general rule should be larger than the receiving article, which will have a tendency to strengthen the solution in metal.

The most philosophical position for the negative plate is the horizontal, but in practice this does not succeed, because the metals used for dissolving are never pure, and their impurities fall on the surface of the article; moreover, the operator cannot examine or remove it. The most practical position is the vertical, the dissolving metal and the receiving article being suspended in the menstruum facing each other, the latter being rather the lower of the two, and both wholly immersed, and the liquid being occasionally stirred to keep it uniform.

If the article to be coated has a very irregular outline, it is necessary to beat the dissolving plate somewhat to its form, so that the two may be nearly equidistant in their opposite parts, and thus a regular metallic deposit obtained. The nearer the receiving object is to the dissolving plate, the more rapid is the precipitation; and a large body of liquid deposits more rapidly and evenly than a small one.

For forming the connections, copper in wires or ribands is the most suitable, as it is one of the best conductors and not expensive. Large connecting-wires allow more copious precipitate than small ones. The article to be coated must be always connected with the zinc of the battery, and the metal to be dissolved with the copper or silver.

Precautions.—In some of the preceding operations, and especially in plating and gilding, the cyanide of potassium is employed. It is proper to state that this substance must be used with caution, both in handling the salt itself, and in breathing the cyanogen atmosphere which is exhaled from its solutions. When the operations are conducted in badly ventilated apartments, the workmen are often affected with giddiness and other distressing symptoms; and their hands are liable to ulceration, particularly if they have been immersed in the solutions. By exercising proper care, and avoiding to inhale the vapor of the cyanides, these inconveniences may be averted; and the other ingredients used in the different processes are not attended with danger. On the contrary, SMEE affirms, perhaps a little too strongly, that those conducting electro-metallurgical operations, generally fatten with their occupation, the minute quantities of sulphate of zinc and sulphuric acid which they imbibe, improving the tone of their stomach, helping digestion, and strengthening the whole frame. The salts of copper, he adds, have the same effects as those of zinc, but, perhaps, upon the whole, must not be made quite so free with. This is the testimony of a medical gentleman; but still, in these as in all other chemical operations, it is prudent to exercise a reasonable care in avoiding to inhale too freely any of the gases given off.

OTHER APPLICATIONS OF ELECTRO-METALLURGY.—It is manifest that the art of depositing metals from their solutions by galvanic agency, admits of a vast variety of applications. The more important of these have already been mentioned, but a few others will be briefly noticed.

Mr. RITCHIE has patented a method for extracting copper from its ores by the following process:—The calcined ore is dissolved in dilute sulphuric acid; this solution is put into a large vessel or trough, and a mixture of two parts water, and one of a saturated solution of sulphate of iron is poured upon it, taking care not to mix it with the lower liquid. An iron plate, as a generating metal, is then placed in the iron solution, and a plate of lead in the copper solution to receive the deposit. The voltaic arrangement is completed without a battery, by simply connecting the two plates by a wire. This process has never been put into practical operation.

NAPIER patented a method of coppering cloth by the electro-process, which forms in that case an excellent fire-proof covering for roofs, railway waggons, *et cetera;* but hitherto the article so manufactured has not succeeded in displacing the cheaper materials commonly employed for the same purpose. The cloth, being previously brushed over with a polish of black lead, and stretched upon a wooden frame surrounded with a copper band, is immersed in a large vat containing the cupreous solution. Battery power may then be applied, or a part of the vat may be partitioned off to receive the dilute acid and zinc. One pound of copper is found sufficient to communicate a perfect solid covering to twenty superficial feet of cloth.

Another method is to stretch the cloth upon a sheet of copper slightly curved, so that the cloth may be in close contact with it all over. The back or hollow side of the copper is then varnished, and a deposit formed by the battery process all over the front of the copper within the meshes of the cloth, and when sufficiently thick, the deposit and cloth firmly united together, may be drawn off the sheet of copper. Mr. J. SCHOTTLAENDER took out a patent, December 8, 1843, for depositing either plain or figured copper upon felted fabrics; he passes the cloth under a plain or engraved copper roller, black-leaded and horizontally immersed in a sulphate of copper solution; the copper is deposited upon the roller as it slowly revolves, and thus the meshes of the cloth are filled with metal, and the design of the roller copied upon it, and the coppered cloth slowly rolled off.

Cells for DANIELL's battery may be made by electro-deposition. For this purpose, coat the inside of a jelly-pot uniformly all over with wax or stearine, and then either brush it over with plumbago, or treat it with phosphorus, silver, and gold solutions; a connection should then be formed with the lower part of the coating, and the deposit effected either by the simple cell process, using the jelly-pot as the outer containing vessel, or by the battery process, using in either case, a sulphate of copper solution.

Hard copper dies may be formed from impressions on sealing-wax, gutta percha, or any other substance used for moulds. All embossed surfaces may be copied with facility, whether they consist of paper or any other material. If porous, they must be first rendered non-absorbent by oil, varnish, or wax, according to the thickness of the texture. Black-lead may be used to impart a conducting surface to seeds and roots, or other solid productions. But delicate leaves or flowers are prepared to receive the deposit by immersion in Mr. PARKES' solution, already described. Electro-coppered leaves, branches, and similar natural objects, are very beautiful. Even the delicate tendrils and hairs of plants may be all perfectly covered by this process. Insects may be coated or copied in the same manner. Every vegetal and animal substance whatever, which will remain undecomposed in the solution of copper for a few hours, can have a metallic mould made from it, or a metallic coating thrown over it.

But one of the most promising applications of the art is to the purpose of engraving and printing. This was the only application, indeed, which first occurred to its inventors, JACOBI, JORDAN, and SPENCER; and the art was pursued for some time with no other useful object in view. Hence its original name, the electrotype, which, although perfectly applicable when it was confined to the copying of objects, such as copper-plates, type, and medals, has long ceased to be appropriate, and does not embrace, in its etymological meaning, the far more important branch of the art, which consists in imparting to objects of use, or ornament, a permanent covering of gold, silver, copper, or some other metallic deposit. The word electrotype, in short, which, in accordance with its Greek origin, expresses the copying, moulding, or modelling of figures or characters by electricity, embraces only a part of the art, which, in its numerous modern applications, is more appropriately termed electro-metallurgy. This is the generic name for the whole. Electro-typing and electro-plating—using the latter term, as it ought to be used, with reference to all the metals, and not to silver alone—constitute its two leading divisions. There are, however, certain processes, such as the reduction of metals from their ores by voltaic agency, which, although correctly expressed by the general name, are contained within neither of these divisions.

One of the first objects pursued by SPENCER was to produce copies or fac-similes of common type, by the electro-process. This attempt was attended with very indifferent success; but, of late, a patent has been taken for a method of preparing stereotype plates, which promises to be of great value. This operation is performed on plates of the common stereotype metal, and consists in depositing a film of hard copper on the face of the letters. By this process, the plates are rendered much more durable, and yield a greater number of impressions without injury. A copper facing is given in the same manner to common type.

There is nothing to prevent forming the stereotype plate itself of deposited copper. A mould may be taken in the common way, either in paper or plaster of Paris, and this being saturated with oil or wax, and carefully covered with a film of black lead, or dipped into PARKES' patent solution, might receive a copper deposit of any thickness. The deposit being taken from the mould, and filled in with plaster of Paris, or gutta percha at the back, could be fixed to a block of wood or stereotype metal; but probably the trouble attending these operations would scarcely be compensated by any advantages gained. Instead of the paper or plaster, gutta percha, softened in boiling water, would form an excellent material for the mould, and would not require the preparation with oil or wax. DE LA RUE has been very successful in applying the electrotype process to many operations in ordinary printing. It has also been applied to plates for printing music, and for embossing soft materials, such as leather.

The multiplication of plain copper-plates, by this process, may seem to be a somewhat circuitous method of doing what is more easily effected by simple rolling and hammering. Yet, to make good copper-plates for engraving, is an operation attended with some difficulty; and those little cavities in the metal, which are found even in the best commercial copper, produce a degree of uncertainty in the engraving. These are avoided, and the process is much simplified, by depositing an electro-type plate on one of the prepared copper-plates. Deposited metal is always perfectly pure, and, by adjusting the power of the battery to the strength of the solution, may be made of any required solidity.

But a higher application of the art is to copy engraved copper-plates, which may be done with great nicety, producing a perfect fac-simile of the original. It matters not how complex the design, or how fine and delicate the execution—the engraved plate may be copied with the same ease and fidelity as the plain plate. The electrotype resembles the daguerreotype in showing its powers to the greatest advantage when it is employed in reproducing the most elaborate tracery. In applying the process, however, to engraved plates, on which the design is always in intaglio, the first electrotype plate that is deposited will be in relief. This plate must therefore be used as a mould for depositing upon it a second plate, which will be a fac-simile of the original. Another plan of forming the mould is to take an impression from the engraved plate, on a perfectly clean surface of lead, by means of a copper-plate press. To avoid the curling of the plate by the pressure, SMEE recommends that, when it is placed upon the lead, another plate be placed above it, before passing through the press. But very good moulds may be formed in white wax, or plaster of Paris, and, probably, still better, and more conveniently, in gutta percha.

The Art Union of London has employed this process to multiply copies of original plates, and it was found that the impressions taken from each electrotype varied from four hundred to one thousand, depending chiefly on the character of the engraving. The multiplication of engraved plates, in the same manner, is usefully carried out at the Ordnance Map Department at Southampton. Each copper-plate map, when finished by mechanical engraving, is transferred to the electrotype department, where any required number of duplicate plates are taken. Electro-metallurgy has, in this case, been of the utmost importance by enabling the Ordnance maps to be published at a moderate price.

The great demand for engraved copper-plates is at the potteries and calico-printing establishments. For use at the potteries, the device must be deeply cut in the copper, from which it is printed on a piece of thin paper, with a composition of arsenite of cobalt instead of the ordinary printer's ink. The paper is then pressed upon the pottery plate before it is glazed, in order that the ink may adhere to it, after which, the paper is washed off. Both the potters and the calico-printers chiefly employ the engraved plates in the form of cylindrical rollers—the plates, when engraved, being bent round into a cylindrical shape, and the edges soldered together. These copper-plates, before they are bent, may be easily multiplied by the electrotype process; but although active attempts were made so early as 1841, to apply the electro-deposition of copper to the preparation of the rollers in the first instance, both by depositing the copper upon wax, or other moulds, to make an entire roller of copper, or by depositing a surface of copper on iron or brass, the practical difficulties met with, in trying these applications, have hitherto been found insurmountable.

Woodcuts are easily multiplied by giving them a coating of black lead, and applying the ordinary process, first to produce a mould, and then a fac-simile in copper. Or a gutta percha impression may be employed with advantage for the mould in this, as in many other cases, for which its use is invaluable. But duplicates of woodcuts are so readily taken by the common stereotype process that this will continue to be generally preferred for common work. At the same time, for good engravings, the electrotype process is preferable. One of the most beautiful series of specimens of printing from electrotypes, is to be found in an illustrated edition of *Thomson's Seasons*, all the woodcuts of which were carefully preserved, and the actual printing performed from electrotype copies.

GLYPHOGRAPHY.—The most successful application of the electrotype to engraving is that mode of producing printing surfaces which has been termed by the patentee *Glyphography*. The following accurate account of the process is given in the last edition of SMEE'S admirable Elements of Electro-metallurgy:—

This branch of art was invented by Mr. E. PALMER; it forms an important feature for the general illustration of printed works, and on that account demands particular consideration. The term glyphography has been given by PALMER, to signify that the original drawing itself is at once engraved, requiring no copying, and in fact scarcely any instruments, except those with which the artist makes his design. The mode in which so extraordinary an end is accomplished appears ridiculously simple when it is detailed. The most essential part of the process is to make all the surfaces for printing as flat as possible, and for this purpose a plate of copper as used for engraving is first procured. This is blackened with the sulphide of potassium, in order that the draughtsman may be enabled to judge of the effect which his drawing would produce, as he proceeds with his work. This blackened plate is warmed, and then filmed with a compound of Burgundy pitch, white wax, rosin, spermaceti, and sulphate of lead, previously fused together. This composition, which is nearly white, must be uniformly spread over the plate, and the thickness should be about the one-thirtieth of an inch. The plate is now ready for the artist, who cuts through the white composition completely down to the blackened copper, and in fact, with the exception of that precaution, makes his drawing in the usual manner. In the selection of tools, the artist should be guided by the manner in which they can completely and clearly cut out the composition; for it is important to make a clear indentation, and not to turn aside the coating and leave a burr. A simple hook, fixed in a wooden handle, a hook filed away on one side, which most effectually cuts away the composition, or a piece of wood tapering to a fine point, are the forms particularly recommended by PALMER. The former instrument is best adapted for very fine lines, the second for larger, and the last for foliage and other free drawings and designs.

When the artist has finished his drawing, the parts of the composition which are removed leave black lines, which have precisely the same relation to the white ground as the black lines in the subsequent print have to the white paper; so that a most important feature in PALMER'S operation, is the exact similarity between the design and the print.

Many improvements have of late been made in the process; such, for instance, as giving a greater depth to the lights; for the ground through which the drawing is made being necessarily very thin, printers found great difficulty in keeping their work clean. To alleviate this, the plate is now submitted to the following process. A roller being made of glue and treacle, such as is used by printers for inking their work, is charged with a composition of gum—thus, turpentine, litharge, and red lead—and then passed lightly over the drawing, taking care that the roller is very lightly charged in the first instance, that it may not stop up the work. When this coat has become dry, which it will in a very short time if put on thin, the operation must be repeated again and again, until a considerable depth has been given to the work.

When this has been obtained for the general work, to the extent required, broad lights should be built up by means of brushes with the same composition, containing more litharge and sulphate of lead, or any other composition which will tend to aid the drying, and is not acted upon by the copper solution in the subsequent process. This part is very essential, or in printing, the paper is pressed to the bottom of what is intended to be a light, and the effect destroyed.

The operator must now allow the whole to get hard, and then with a magnifying glass go carefully over it, and remove anything which may have accidentally got into the lines. He must also then carefully brush it over with the best plumbago, taking great care to rub all out of the lines, or the block, after it is formed, prints rotten by the lines not being sound and firm.

The drawing is now ready to receive a deposit of copper, and the power of the battery must be carefully regulated to prevent too rapid a decomposition, or the copper is apt to grow over some parts if the line is not well cleaned out, and disappoint the artist by work not being copied, which he imagined he had put in.

Having obtained a sufficient thickness in the electrotype trough, and this must vary according to the size of the drawing, the deposited plate is separated, and the back trimmed to receive a layer of type metal, and then, having made the face perfectly flat, the back is turned off, and mounted upon a block of wood similar to a stereotype. Many touches, to relieve different parts, may then be readily put in by a person accustomed to use the graver; indeed, much time is saved by removing the composition altogether in some parts, and putting in any little touches afterwards to give relief to the darks.

The deepening of the work by the rolling process was a great improvement, by giving to the artist a plate with a much thinner ground than was at first used; but it was subsequently found by Mr. HAWKINS, who now carries on the process, that he could likewise form a block upon a common etching ground, which had been so much desired by those accustomed to etching; indeed, practice has now enabled him to form a surface block from almost any engraved plates.

Many very beautiful subjects have been done by this process. Some of the most successful are those well-known prints of the Bottle by CRUIKSHANK; but the subjects best adapted are maps, or writing of every description, and here it stands unrivalled both for price and quality.

There is another branch of art to be noticed, which is an invention called the electro-tint, and which may be dismissed in a very few words. A plain copper-plate is procured, upon which the artist makes a painting with some substance insoluble in the solution of sulphate of copper. The plate is placed in the solution and a reverse made, which is at once ready for the printer.

A great many specimens of the electro-tint have been published at different times, and of various degrees of excellence. Sometimes the electro-tint cast is used to print from the hollows, at others from the elevations; thus, in one case, it forms a kind of engraving, at another, a surface similar to that of a woodcut.—*Smee.*

Nature Printing.—One of the most beautiful applications of the Electrotype is to Nature-Printing—a method of producing impressions of plants, and other natural objects, in a manner so truthful, that only a close inspection reveals the fact of their being copies. So distinctly sensible to the touch are the impressions, that it is difficult to persuade those unacquainted with the manipulation, that they are the production of the printing press. The process, in its application to the reproduction of botanical objects, represents the size, form, and color of the plant, and all its most minute details, even to the smallest fibre of the roots. This art has been brought to great perfection, within the last few years, by Mr. HENRY BRADBURY, of the firm of BRADBURY and EVANS, who explained the history and details of the process in a lecture which was read before the Royal Institution in May, 1855; and from this lecture the following particulars are given.

The distinguishing feature of the process, compared with other modes of producing engraved surfaces for printing purposes, consists, firstly, in impressing natural objects—such as plants, mosses, sea-weeds, feathers, and embroideries—into plates of metal, causing, as it were, the objects to engrave themselves by pressure; and, secondly, in being able to take such casts or copies of the impressed plates as can be printed from at the ordinary copperplate press. This secures, on the one hand, a perfect representation of the characteristic outline of the plant, as well as that of some of the other external marks by which a plant is known, and even in some measure its structure, as for instance in the venation of ferns, and the leaves of flowering plants; and on the other hand, affords the means of multiplying copies in a quick and easy manner, at a trifling expense compared to the result obtained—and to an unlimited extent.

The great defect of all pictorial representations of botanical figures, has consisted in the inability of art to represent faithfully those minute peculiarities by which natural objects are often best distinguished. Nature-printing has, therefore, come to the aid of this branch of science in particular, whilst its future development promises facilities for copying other objects of nature, the reproduction of which it is impossible for the human hand to execute; and even were it possible, it would involve an amount of labor scarcely adequate to the results obtained.

Although considered for some years past in various parts of Europe as a new art, the idea, says Mr. BRADBURY, is by no means so recent as is supposed; much less is there ground for the Austrians to assert their exclusive right to the priority of the invention, merely on account of the first application of the process, in its fullest extent, in the Imperial Printing-office at Vienna. Nature-printing is nothing more than an application of facts worked out by various persons, in different countries, under very different circumstances, and at very different periods.

On account of the great expense attending the production of woodcuts of plants in early times, many naturalists suggested the possibility of making direct use of Nature as a copyist, and Nature herself, in her mysterious operations, seems to have given the first hint upon the subject in the beautiful and accurate impressions of ferns to be seen in the coal formations. In the Book of Art, by Alexis Pedemontanus, printed in the year 1572, and translated into German by WECKER, may be found the first recorded hint as to taking impressions of plants. At a later period—in the *Journal des Voyages*, by M. DE MONCOYS, in 1650, it is mentioned that one WILKENSTEIN, a Dane, gave instructions in making impressions of plants. The process adopted to produce such impressions at this period, consisted in laying out flat and drying the plants. By holding them over the smoke of a candle, or an oil lamp, they became blackened in an equal manner all over; and by being placed between two soft leaves of paper, and rubbed down with a smoothing-bone, the soot was imparted to the paper, and the impression of the veins and fibres was so transferred.

LINNÆUS, in his *Philosophia Botanica*, relates that in America, in 1707, one HESSEL made impressions of plants; and between 1728 and 1757, Professor KNIPHOF, at Erfurt, in conjunction with the bookseller FUNKE, established a printing-office for the purpose. He produced a work, entitled *Herbarium Vivum*, in twelve folio volumes, and containing one thousand two hundred plates. These impressions were obtained in a manner very similar to the method above mentioned, but with the substitution of printer's ink for lamp-black, and flat pressure for the smoothing-bone. A new feature at this time was introduced—that of coloring the impressions by hand, according to nature—a proceeding which, though certainly contributing to the beauty and fidelity of the effect, yet had the disadvantage of frequently rendering indistinct, and even sometimes totally obliterating, the tender structure and finer veins and fibres. Many persons at the time objected to the indistinctness of such representations, and the absence of the parts of fructification; but it was the decided opinion of LINNÆUS, that to obtain a fac-simile of the difference of species was sufficient.

SELIGMANN, an engraver at Nuremberg, in 1748, published in folio plates figures of several leaves he had reduced to skeletons. As he thought it impossible to make drawings sufficiently correct, he took impressions from the leaves in red ink, but no mention is made of the means he adopted. Of the greater part he gave two figures, one of the upper and another of the lower side. About the year 1790, HOPPE edited his Ectypa Plantarum Ratisbonensium, and also his Ectypa Plantarum Selectarum, the illustrations in which were produced in a manner similar to that employed by KNIPHOF. These impressions were found also to be durable, but still were defective. The production of impressions could only take place very slowly, as the blacking of the plants with the printer's ball required much time. Rude as the process was, and imperfect the result, it was nevertheless found that the figures thus produced were far more characteristic than any which artists could produce. The fault of the method consisted in its limited application and its incompleteness; since the fragile nature of the prepared plant, if ever so carefully treated, would admit of but very few copies being taken, and where any great number would have been required, many plants must have been prepared, a circumstance which was in itself a great obstacle.

In the early part of the present century, various improvements in the process were introduced, and at length, about the year 1830, the idea occurred of fixing an impression of the prepared plant in a plate of metal by pressure. It appears, on the authority of Professor THIELE, that PETER KYHL, a Danish goldsmith and engraver, established at Copenhagen, applied himself for a length of time to the ornamentation of articles in silver-ware, and the means he adopted were, taking copies of flat objects of nature and art in plates of metal by means of two steel rollers. Various productions in silver, by this process, were exposed in the Exhibition of Industry held at Charlottenburg, in May, 1833. In a manuscript, written by this Danish goldsmith, in May, 1833, is suggested the idea of applying this invention to the advancement of science in general. The plates accompanying this description represented printed copies of leaves, of linen and woven stuffs, of laces, of feathers, of birds, scales of fishes, and even of serpent skins.

The manuscript contains ample and clear instructions to carry out the method. He states, that to fix an impression into a plate of copper, zinc, tin, or lead, properly prepared for the purpose, a rolling machine with two polished cylinders of steel is required; if a *leaf*, quite dried and prepared, is placed between a polished steel plate half an inch thick, and a thoroughly heated lead plate with a fine surface, and these two plates with the leaf between be run speedily between the cylinders, the leaf will, by the pressure, yield its form on the softer lead plate, precisely as it is shaped, with all its natural raised and sunken parts. He adds, that leaves that are to be printed must first be spread upon a clean sheet of paper and placed upon a warm oven; a second sheet put over them is to be strewn over with sand, and the whole left to dry under a weight. This done, the leaves are taken out with due precaution, and placed for a quarter of an hour into water. They are dried again in the same way, and this manipulation is repeated four or five times. By this means he always found that the leaves gained in tenacity and firmness, that they lose all their moisture, and become more fit to be stamped. Objects, such as laces, weavings, figured ribbons, and such like, could be printed without any preparation, provided they were spread flat between the plates.

It would appear, says Mr. BRADBURY, from the practical hints here given, that PETER KYHL was no novice at the process. He distinctly points out what he conceives to be its value by the subjects which he tried to copy; and he enters into detail on the precautions to be observed in the operation of impressing metal plates so as to insure successful results. His manuscript explains that he had experimented with copper, zinc, tin, and lead plates. Still there existed obstacles which prevented him from making a practical application of his invention. In the case of zinc, tin, and copper, the plant, from the extreme hardness of the metals, was too much distorted and crushed; while in lead, though the impression was as perfect as could be, there were no means of printing many copies; as it was not possible, after the application of printer's ink, to retain the polished surface that had been imparted to the lead plate, or to cleanse it so thoroughly as to allow the printer to take impressions free from dirty stains. This was a serious obstacle, which was not compensated for even by the peculiar rich surface of the parts that were impressed, attributable to the lead being more granular than copper, and which is so favorable to adding density or body of color, without obliterating the tender veins and fibres. PETER KYHL died in the same year that he made known his invention. At his death, his manuscripts and drawings were deposited in the archives of the Imperial Academy of Copenhagen, where they remained for upwards of twenty years: and it is a remarkable fact, that, shortly after his death, was discovered the only thing wanting to render the process, as explained by him, at once available for practical purposes. Had KYHL lived to prosecute his experiments, he might have accomplished more than he did without requiring the aid of other means. It was he who discovered how to take impressions in metal plates, by using steel rollers.

This is the first element in the process of nature-printing. It fell to Dr. FERGUSON BRANSON, of Sheffield, to suggest the second, and the most important. In 1847, this gentleman commenced a series of experiments, an interesting paper upon which was read before the Society of Arts in 1851; and therein, for the first time, was suggested the application of the electrotype, which is now the most essential feature in nature-printing. Having taken in gutta-percha some impressions of ferns, the singularly beautiful manner in which the exact character of the plant was transferred to the gum, suggested to him the possibility of printing from the gutta-percha itself, so as to produce on paper a fac-simile of the plant. That experiment partially succeeded, and curiously tested the elasticity of the substance; for the impression remained uninjured, after being subjected to the great pressure of a copperplate roller. The printer, however, found it impossible so thoroughly to cleanse the ink from the margin around the impression, as not, when printed, to leave a dirty stain on the paper. The impressions thus produced were very accurate; but the process was valueless as regards multiplication of the prints. It then occurred to Dr. BRANSON that an electrotype copy would obviate the difficulty.

He afterwards stated that he abandoned the process of electrotyping in consequence of his finding it tedious, troublesome, and costly to produce large plates. Having occasion, however, to get an article cast in brass, he was astonished at the beautiful manner in which the form of the model was reproduced in the metal. He determined, therefore, to have a cast taken in brass from a gutta-percha mould of ferns, and was much gratified to see the impression rendered almost as minutely as by the electrotype process; but, however curious his individual specimens, the process produced no practical result.

In 1849, Professor LEYDOLT, of the Imperial Polytechnic Institute at Vienna, availed himself of the resources of the Imperial Printing-office to carry into execution a new method he had conceived of representing agates, and other quartzoze minerals, in a manner true to nature. This able philosopher had occupied himself for a considerable period in examining the origin and composition of these interesting mineralogical objects. In the course of his experiments and investigations, he had occasion to expose them to the action of hydrofluoric acid, when he found, in the case of an agate, that many of the concentric scales were totally unchanged, while others, to a great extent decomposed by the acid, appeared as hollows between the unaltered scales. It occurred to LEYDOLT that the surfaces of bodies thus corroded might be printed from, and copies multiplied with the greatest facility.

The simplest mode for obtaining printed copies is to take an impression direct from the stone itself. The surface, after having been etched, is well washed with dilute hydrochloric acid, and dried; then carefully blackened with printer's ink. By placing a leaf of paper upon it—*India paper* and *Chalk paper* are the best adapted for the purpose—and by pressing it down upon every portion of the etched or corroded surface with a burnisher, an impression is obtained, representing the crystallized rhomboidal quartz *black*, and the weaker parts, that have been decomposed by the action of the acid, *white*. It requires but a small quantity of ink—and particular care must be exercised in the rubbing down of the impression. This mode is good as far as it goes—but it is slow and uncertain—and incurring a certain amount of risk, owing to the brittle nature of the object; and the effect produced is not altogether correct, since it represents those portions black that should be white, and *vice versâ*.

The stone is not sufficiently strong to be subjected to the action of a printing press; an exact fac-simile cast of it must, therefore, be obtained, and in such a form as can be printed from. To effect this, the surface of any such stone, previously etched by corrosion, must be extended by imbedding it in any plastic composition that will yield a perfectly flat and smooth surface, so that the surrounding surface of the plastic composition will be exactly level with the surface of the etched stone: all that is necessary now, is to prepare it for the electrotype apparatus, by which a perfect fac-simile is produced, representing the agate impressed, as it were, into a polished plate of copper. This forms the printing plate. The ink in this case, as opposed to the mode before referred to, is not applied upon the surface, but in the depressions caused by the action of the acid on the weaker parts; the paper is forced into these depressions in the operation of printing, which results in producing an impression in relief—a feature that is rather peculiar to the process, as the raised appearance, especially in the case of plants, adds very much to their effect. The impressions printed in this latter manner present far more beautiful and natural representations, since the crystallized quartz portions are represented *white*, while the decomposed parts appear *black*.

Professor LEYDOLT, however, suggests that some corroded stones are better suited sometimes for one method of representation than the other; and attention should be paid to this while the stones are being exposed to the action of the acid. He considers that important advantages will result to science from the perfect faithfulness of such representations, and from the facility and inconsiderable expense of their production.

Other objects in geology—such as the fossil remains of fishes, plants, *et cetera*—can in some cases be copied with remarkable resemblance to the original. In operating upon this class of objects, it is desirable that the original should be as flat as possible, as the smoother the general surface is, the more successful will be the effect produced. A mould in the first place is taken with gelatine or liquid gutta-percha, the elasticity of which materials are favorable for flattening the mould without distortion when separated from the original—a mode that is to be preferred to depositing copper direct upon them, since it is very much more easily manipulated, and without the slightest risk of damaging the originals, owing to the absence of pressure. This gelatin or gutta-percha mould is rendered metallic or conducting in the usual way by the application of plumbago, and copper is deposited until of sufficient thickness to form a printing plate.

In 1852, Mr. AITKEN, of Birmingham, followed the footsteps of KYHL in various experiments made by him in Britannia metal. He took impressions of lace, skeleton-leaves, feathers, and other objects in this metal, for the purpose of ornamentation, in the same way as KYHL is said to have done in articles of silver. About this period Dr. BRANSON again made experiments, and endeavored to bring nature-printing into practical operation. He too tried impressions on Britannia metal, not altogether with the view of printing direct from such plates, desirable as it would be to dispense with the operation of taking casts—but of transferring impressions to stone; and after printing an impression in some neutral tint, to resort to coloring by hand.

In the Imperial Printing-office of Vienna, the first application of taking impressions of lace on plates of metal, by means of rollers, took place in the month of May, 1852: it originated in the Minister of the Interior, BAUMGARTNER, having received specimens from London, which so much attracted the attention of the Chief Director, that he determined to produce others like them. This led to their employing gutta-percha in the same manner that BRANSON had used it; but finding this material did not possess altogether the necessary properties, the experience of ANDREW WORRING, the superintendent of the printing establishment, induced him to substitute lead, which was attended with remarkable success. Professor HAIDINGER, on seeing specimens of these laces, and learning the means by which they had been obtained, proposed the application of the process to plants. The results of these experiments, which consisted of specimens of lace, leaves, plants, mosses, serpent-skins, the wing of a bat, agates, fossils, and petrifactions, as well as those of Professor LEYDOLT above referred to, appeared in the fifth volume of Memoirs of the Imperial Academy, published at Vienna, in 1850.

Up to this time, however, in England, notwithstanding the above-mentioned experiments, the discovery had not assumed any practical form. Nature-printing owes its present success to the electrotype, which was then, and even at the present time is, the only means by which faithful copies can be taken of those delicate fibrous details that are furnished in the examples of the impressions of botanical and other figures in metal. It may be said to be owing to the extensive scale upon which the process of the electrotype is conducted in the Imperial establishment, that WORRING was enabled to render the process of nature-printing practically available as a Printing Art, and that which was done for it by WORRING in Germany, Mr. BRADBURY has accomplished in England.

The mode of printing the electrotype plates of plants, is the same as in ordinary copperplate printing, where the impression is produced by passing the inked plate, with the sheet of paper laid upon it, through a pair of rollers, one of which is covered with four or five thicknesses of blanketing, which causes the peculiar raised or embossed appearance of the impression.

In such cases, where there are three, four, or more colors, for instance,—as in flowering plants, having stems, roots, leaves, and flowers,—the plan adopted in the inking of the plate, is to apply the darkest hue first, which generally happens to be the roots—the superfluous color is cleaned off—the next darkest shade, such as perhaps the color of the stems, is then applied—the superfluous color of which is also cleaned off: this mode is continued until every part of the plant in the copperplate has received its right tint. In this state, before the plate is printed, the colors in the different parts of the copper look as if the plant was imbedded in copper. By putting the darkest color in at the beginning, there is less chance of smearing the lighter ones: the printer, too, is not only able, by this means, to blend one shade into another, but to print all the colors at one single impression.

The *first* practical application of nature-printing for illustrating a botanical work, and which has been attended with considerable success, is CHEVALIER VON HEUFLER'S work on the Mosses, collected from the Valley of Arpasch, in Transylvania; the *second—the first in this country*—is the *Ferns of Great Britain and Ireland* in course of publication, under the editorship of Dr. LINDLEY, and printed by Messrs. BRADBURY and EVANS. Ferns, by their peculiar structure and general flatness, are especially adapted to develop the capabilities of the process, and there is no race of plants for which minute accuracy in delineation is of more vital importance than the ferns; in the distinction of which, the form of indentations, the general outline, the exact manner in which repeated subdivision is effected, and most especially the distribution of veins scarcely visible to the naked eye, play the most important part. To express such facts with the necessary accuracy, the art of a DAGUERRE or a TALBOT would have been insufficient until nature-printing was brought to its present state of perfection.

COPYING DAGUERREOTYPE PICTURES.—The triumph of the electrotype, properly so called, or one at least of the most beautiful applications of the electro-deposition of copper, is that of copying daguerreotype pictures; the process, moreover, is perfectly simple, and is thus minutely described by Mr. GORE, with a remarkable observation made by himself on the subject:—Solder a wire to one corner of the back of the picture, then varnish the back and edges and let them dry, hang it in a perfectly clean sulphate of copper solution—one free from dust on its surface—and connect it with one or two pairs of small SMEE'S batteries; in the course of twenty or twenty-four hours, when the deposit is sufficiently thick to remove, take it out, well wash it, and wipe it perfectly dry, then with a strong pair of scissors cut off the edges all round; the original and copy may then easily be separated by inserting the point of a knife or the end of a thin wedge of hard wood between them at the edges. If the process has been carefully conducted, and the original picture is a strong one, a most beautiful and vivid copy will be obtained; a number of copies may be taken from the same original, especially if it is a strong one, and has been well fixed by FIZEAU'S process; but the intensity of the copies and of the original appears gradually to diminish in each succeeding trial.

Under such circumstances, especially with very regular action of the battery, a fine deposit, clear solution, and vivid original picture, Gore observed a most extraordinary effect, namely, that the picture had not disappeared, even in twenty-four hours, although the deposit upon the original plate had constantly increased in thickness, but had penetrated quite through the deposit, and appeared distinctly upon the back. Gore has remarked the image repeatedly on the back as well as upon the front of deposits as thick as an address card. Sometimes the image was optically positive, and sometimes negative.

Utility of Electro-metallurgy.—The different cases in which electro-metallurgy is serviceable for the various departments of printing have been now described, and extensive as are their present applications, doubtless there is still much to be effected in this department alone.

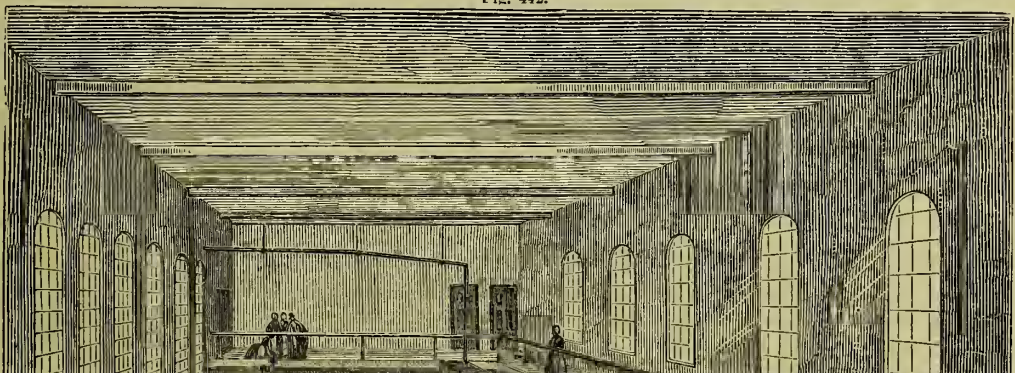
The same may be affirmed of its application to the arts in general. It may, indeed, says Smee, be a matter of conjecture to what extent this science may be ultimately carried out, or to what other purposes it may be applied in years to come, but were it never to be directed otherwise than it has already been, were it to stop for ever at the point to which it has now been brought, no one can deny that it is a most valuable acquisition; in short, one may safely assert that no other discovery ever presented capabilities at once so many, so various, so interesting, or so valuable.

Doubtless the galvanic fluid will, before long, be as important to the manufacturer as the heat of a furnace. Now-a-days, a person may enter a room by a door having finger-plates of the most costly device made by the agency of the electric fluid; the walls of the apartment may be covered with engravings, printed from plates originally etched by galvanism, and multiplied by the same force; the chimney piece may be decked with ornaments made in a similar manner. At dinner, the plates may have devices given by electrotype engravings, the salt spoons gilt by the galvanic fluid, and the table decorated with costly electro-silver-plated objects. All these, and many other applications, there are at present, but one must still look forward to the most important properties of the electric current derived from the galvanic battery; for although great and glorious are the triumphs of science detailed in this work, yet the prospect of obtaining a power which shall supersede steam, exceeds in value all these appliances. For to cross the seas, to traverse the roads, and to work machinery by galvanism, or rather electro-magnetism, will certainly, if executed, be the most noble achievement ever performed by man.

Those who are, comparatively, unacquainted with electricity and galvanic apparatus, may meet with some little trouble in entering upon the science of electro-metallurgy; but commencing upon a right method, their first trouble will be their last; and let them always bear in mind, that without trouble no great good was ever accomplished.—*Smee.*

Statistics.—Birmingham has always been the chief seat of the electro-plating and gilding trade, by which a complete revolution has been effected in the art of coating with metals. It was introduced by Mr. Elkington in 1840, amidst much discouragement and opposition. Manufacturers and retail tradesmen were alike opposed to the change. All sorts of objections

Fig. 442.



writes a correspondent of the *Morning Chronicle*, were started, and the silversmiths refused in many instances to take the articles into their shops, *even to retail them at a profit.* But these and innumerable other difficulties were ultimately powerless to obstruct the progress of art. The wonderful nature of the agency by which the result was effected excited curiosity; but when it was seen that the operation was so simple and so unerring, that the most elaborate articles could be plated with as much perfection as a common sheet of metal, and that for beauty and elegance, electro-plated goods were fully equal to objects chased in solid silver or gold, a demand for them began to arise. As early as the year 1841 the business had assumed great importance, and in 1842, the Messrs. ELKINGTON found constant employment for as many as three hundred persons. The manufacture has since gone on increasing, and the patentees now employ seven hundred people. The annexed engraving—Fig. 442—will convey an idea of the interior arrangements of this extensive factory, of which it is an accurate delineation.

The principal advantages of the electro-plated goods are, that they are manufactured in the same manner as silver, the ornamental parts being chased in solid metal; that, where joints are necessary, none but hard solder is used; that the base is composed of a purified white nickel metal of great durability, and of the same color as the exterior; that the union of the surface and base is perfect, forming one body; that the plating on the more prominent parts is, from the nature of the process, stronger than on those less exposed to wear; that every description of style, however elaborate, and whether embossed or engraved, can be plated with the same facility as a plain surface; that with moderate care these goods will last from ten to twenty years, and that they can be replated when injured or worn—which, under the old processes, could not be done—at a comparatively trifling expense.

The show rooms of Messrs. ELKINGTON and MASON contain specimens not only of electro-plated articles, such as *épergnes*, candlesticks, candelabra, bronze statues and statuettes, vases, and countless other objects of domestic use and adornment, of modern and of antique art, but of new adaptations of the electro-process to the service of the sciences. They exhibit beautiful specimens of the vegetation or growth of copper by electrical agency; of iron coated with zinc or copper; of flowers and shrubs, with all their delicate anatomy and tracery, covered with metal, and thereby rendered imperishable; and of birds and insects coated and preserved by the same wonderful but simple means. Leaves and flowers of gold and silver are thus manufactured, nature being made to form the basis of art in a manner hitherto unknown. Flowers and shrubs, insects, and other natural objects which it is wished to preserve, are coated with zinc, copper, silver, or gold. Where the filming is of the less valuable metals, it may be painted of the color of nature; and the specimens in this way may be preserved for centuries. So delicate is the operation of the electric current, that even a spider's web may be plated with gold or silver. The Editor, in inspecting this establishment, was greatly struck with different kinds of plotting scales, in the centre of which were embedded beautiful bronze reliefs. The workmen employed are, as might be expected, of a superior class.

ENAMELS.—*Email*, French; *Schmelzglas*, German; *Encausti*, Latin.—Enamels are substances of the nature of glass, differing from it, however, by a greater degree of fusibility or opacity. They are colored by different metallic oxides, to which certain persistent fusible salts are added, such as the borates, fluorides, phosphates, *et cetera.*

The ancients carried the art of enamelling to a very high degree of perfection, and beautiful specimens of their ingenuity are occasionally found, of which neither the composition nor the mode of applying it is known. Then, as at present, each artizan made a mystery of the means that succeeded best with him, and thus a great number of curious processes have been buried with their originator. Another cause, says URE, contributes powerfully to this kind of declension in the arts. Among the vast numbers of prescriptions which have been given or published for the formation of enamels, there are several in which substances are mentioned that can no longer be procured, whether owing to a change of denomination, or because they cannot now be found in commerce, or else they are not of the same nature as of old. Hence, in numerous instances, it is found impossible to obtain satisfactory results. Owing to this, it is desirable that new investigations should be undertaken, and for these, *raw materials of the purest kind* selected. Dr. LEWIS states that he once produced an enamel of a beautiful color, but he was unable to succeed a second time, though he took infinite pains, and tried a multitude of experiments. This certainly must have been owing to his not noting the proportions of the ingredients in the first assay, or else to his not being able to obtain them in the same state. It is a fact, that an additional quantity of a metallic oxide, beyond a certain limit, instead of deepening the color, actually destroys it; further, the degree of heat to which a mixture is subjected often militates against the desired result.

A singular circumstance may be here noticed, which is, that a vitreous mass containing copper, when removed from the melting pot, sometimes only exhibits a faint greenish hue; still, in this state, nothing more than simple exposure to a gentle heat is requisite to throw out a brilliant red.

This alteration in color is very curious. It may consist in the proneness of the copper to pass from the state of suboxide—Cu_2O—into that of protoxide—CuO—by the absorption of oxygen,

$$Cu_2O + O = 2\,CuO,$$

which tinges glass green; but for this to occur at so incipient a temperature is remarkable.

Glass containing gold exhibits the same singular change of tint under similar circumstances.

M. SPLITTBERGER displayed specimens of glass ten years ago, into the composition of which gold entered as a chloride. They were white, but when re-heated in the flame of a spirit lamp, they assumed a deep-red tinge. If, again, this red glass be subjected to the heat of an oxygen blowpipe, it loses nearly all its color.

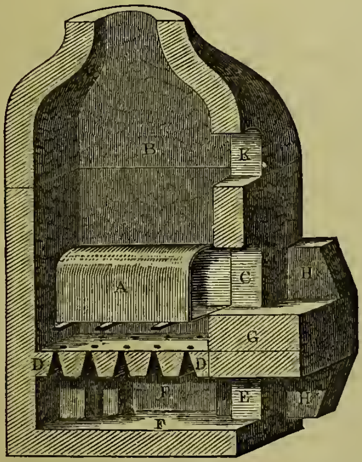
These metamorphoses have been vaguely attributed to different degrees of oxidation in the metal; but if this be the case, it is strange that mere exposure to a slight temperature can effect any chemical variation in the interior of a solid mass of glass, which has already undergone a heat far more intense. **Beckmann** found that metallic gold gives the red color as well as its oxide, and it appears scarcely to admit of a doubt, that in a metal so easily reduced, the whole of the oxygen must be expelled long before the enamel has reached its melting point. It has for many years been known that silver imparts a color to glass while in the state of metal, and everything leads one to suppose that the case is the same with gold.

The material employed of old to tinge glass red was the suboxide of copper; but on the discontinuance of the art of glass-painting the dependent manufacture of ruby glass of course ceased, and the process became so entirely extinct, that the idea generally prevailed that the color in question was derived from gold. In 1793, the French government actually collected a quantity of ancient glass with the view of extracting the gold by which it was supposed to be tinged. It is remarkable that the knowledge of the copper-red should have been so completely lost, though printed receipts have always existed detailing the whole method. **Baptista Porta** gives a recipe, noticing at the same time the difficulty of following it. **Kunkel** discovered that gold, when melted with flint glass, imparted a fine ruby tint; and the fact that he derived great profit from this invention, was the cause of his being so reticent upon the subject, while his successors have kept the secret of his method as much as possible inviolate to the present day.

The Venetians are still in the possession of the best processes, and they supply the French and other nations with the finest kind of enamel.

Before entering upon the different varieties of enamels, it is desirable to describe the furnace in which they are fabricated. The enamel furnace is represented in Fig. 443. The burning is effected in a muffle, A, a thin clay vessel heated from without, the interior of which is nowhere in connection with the fire-place, B, of the furnace, and the mouth of the muffle fitting exactly the aperture, C. The pierced plate of clay, D D, answers the purpose of a grate, and is supplied with air by three apertures, E E, of the ash-pit, F. A ledge, G, is erected for convenience before the working-hole, C, and is supported by the cheeks, H H. The aperture, K, is for the purpose of stirring the fire, and can be closed like any one of the others by a clay door.

Fig. 443.



Before the work is begun, the furnace must be made red-hot; the pieces are then inserted, and the aperture, C, is closed in such a manner as to leave a small crack, through which the fusion can be watched. The success of the enamelling process depends upon a proper mean being maintained between that temperature which would cause the enamel to flow, and that at which it only imperfectly softens and its surface remains rough. The most common defect in the appearance of enamelled articles is caused, however, by air-bubbles, which have not found an opportunity of fully effecting their escape. These either occasion a protuberance, or, when they have burst, a concavity, which frequently render it necessary, subsequently, to give a finish to the piece.—*Knapp.*

Enamels are distinguished into transparent and opaque; in the former, all the elements have experienced an equal degree of liquefaction, and are thus run into crystal glass; whilst, in the others, some of them have better resisted the action of heat, so that their particles retain sufficient aggregation to prevent the transmission of light. This effect is produced particularly by the oxide of tin, as will be perceived when treating of white enamel. The frits of enamels that are to be applied to metallic surfaces require greater fusibility, and should, therefore, contain more flux; and the sand used for these should be calcined beforehand with one-fourth its weight of chloride of sodium; sometimes, indeed, metallic fluxes are added, as minium or litharge. For some metallic colors the oxides of lead are very injurious; in such a case, recourse must be had to other fluxes.

The following mixtures have been found serviceable for purples, blues, and some other delicate colors:—

Three parts of silicious sand, one of chalk, and three of calcined borax; or, three of glass—of broken crystal vessels—one of calcined borax, one-fourth of a part of nitrate of soda, one part of well-washed antimoniate of potassa. These compositions afford a very white enamel, which accords perfectly well with blue.

It is obvious that the composition of this primary matter may be greatly varied; but one should never lose sight of the essential quality of a good enamel, which is, to acquire, at a moderate heat, sufficient fluidity to take a shining surface without running too thin. It is not perfect fusion that is wanted, but a pasty state, of such a degree as may give it, after cooling, the aspect of having suffered complete liquefaction.

Dead-white Enamel.—Greater nicety is necessary in the choice of its materials than any other, hence the frit employed in this case should be itself composed of *perfectly pure ingredients.* But a frit should not be rejected hastily because it may be somewhat discolored, since this may depend upon two causes—either on some metallic oxides, or on fuliginous particles proceeding from vegetal or animal substances. Now, the latter impurities may be easily removed by means of small quantities of binoxide of manganese, which has the property of readily parting with a portion of its oxygen, and of thus facilitating the combustion—that is to say, the destruction—of the coloring carbonaceous matter. Manganese, indeed, possesses a tinctorial power itself on glass, but only in a very high state of oxidation, and when reduced to the lower state, as is done by incombustible matters, it no longer tinges enamel combinations. Hence the proportion of manganese should never exceed what is requisite; for any surplus would cause color. Sometimes, indeed, it becomes necessary to give a little manganese tinge in order to obtain a more agreeable shade of white, as a little azure blue is added to linens to brighten or counteract the dullness of their yellow tint.

A white enamel may be conveniently prepared also with a mixture, composed of two parts of tin and one of lead calcined together; of this combined oxide, one part is melted with two parts of fine crystal and a very little manganese, all previously ground together. When the fusion is complete, the vitreous matter is to be poured into clear water, and the frit is then dried and remelted. The pouring into water and fusion are sometimes repeated four times, in order to secure a very uniform combination. The crucible must be carefully screened from smoke or flame. The smallest portions of oxide of iron or copper admitted into this enamel will destroy its value.

Some practitioners recommend the use of the washed alkaline antimoniate for white enamel; but this product cannot be added to any preparation of lead or other metallic oxides; for it would tend rather to tarnish the color than to clean it up, and it can be used, therefore, only with ordinary glass or with saline fluxes. For three parts of white glass, without lead, one part of washed antimoniate of potassa is to be taken; the substances are well ground together, and fused in the common way.

CLOUET has written the best paper upon enamels, and the Editor, therefore, translates much of the interesting matter contained in it relative to their composition, *et cetera.*

WHITE ENAMEL.—This enamel, either for earthenware or for applying on metals, is composed as follows: A mixture of lead and tin is calcined, which may vary in the following proportions—namely, for one hundred parts of lead, fifteen, twenty, thirty, and even forty of tin. The mixture of these two metals calcines readily with the contact of air. As soon as this alloy is heated to the point of incipient redness, it burns like charcoal, and calcines very fast. The best quantities are those which, for one hundred of lead, contain twenty to twenty-five of tin. In proportion as the calcination is effected, the heated part is withdrawn, and the rest is continued to be oxidized till the whole becomes pulverulent. As some small grains always escape, the oxide obtained is passed a second time into the fire in order to heat it completely, which is known to be the case when it no longer sparkles—that is to say, when one no longer observes parts which burn like coals, and the whole appears of one uniform color.

When the proportion of tin exceeds twenty-five or thirty, a stronger fire is required. However, by varying the power of the fire, one may ascertain that which suits best for the bodies operated upon. One hundred parts of the above mixture are usually taken, and the same of sand. Twenty-five to thirty pounds of chloride of sodium are now to be added, the whole well rubbed together, and the mixture put to melt on the furnace in which the ware is baked. This article is usually placed in sand, or lime slaked in the air, or on ashes.

The lower part of the mass is pretty generally not well melted. Nevertheless, this does not prevent the substance, when brayed and afterwards put in the goods, becoming very white in baking in the furnace. When withdrawn from under the furnace it is not white; it is often even rather black: usually, it is marbled a black, grey, and white.

This method of procedure is that which is practised in the potteries. In the compositions intended for such works, the proportion of twenty-five of tin to one hundred of lead is scarcely exceeded; even for common earthenware, potters are satisfied with fifteen of tin to one hundred of lead.

It is obvious that, if it be wished to obtain a whiter and more fusible enamel, the quantity of sand must be diminished, while that of the chloride of sodium must be increased; as the whiteness and opacity depend on the quantity of tin, twenty-five or thirty of the *calcine* may be taken to one hundred parts. For example, one hundred of the mixture, sixty of sand, and twenty-five of metallic chloride, give a very fusible composition.

But it is to be observed that some further manipulations must be practised when enamels are to be obtained fit for being laid on metals, and to have them in full perfection.

In that case, crude sand is not used; it is calcined with one-fourth of its weight of chloride of sodium over a strong fire, either on the small scale in a crucible, or on the large under a furnace; further, if a very fusible enamel is desired, it is mixed with minium or with lead calcined in this first operation, nearly in the same proportion as with salt—that is to say, one-fourth; a white mass is then obtained, half-melted and porous, which is pulverized, and is used in the composition of the enamel instead of the sand. This substance may even be diminished to fifty per cent. if a very fusible enamel is desired. It depends also on the kind of *calcine* employed; for that which contains most tin is least fusible.

When fluxes for the colors are required, the same compositions above mentioned are used, except that little or no tin is put in the lead. In the latter case, minium is usually taken. This flux is good for certain colors, but not for all. It is found that fluxes into which oxides of lead enter, tarnish; in that case, other fluxes are formed without oxide of lead; nitrate of soda and borax are usually employed to make these glasses; no calcine of tin is used. The following results were found by CLOUET:—Three parts of silicious sand, one of chalk, three of calcined borax, give a substance suitable to serve as a flux for purples, blues, and other delicate colors; three of white *gobleterie,* one of calcined borax, one-fourth part of nitrate of soda, one part of white oxide of antimony made with well-washed nitrate of soda, yield a very white enamel, which may serve also as a flux for purple, and especially for blue.

Sixty parts of enamel sand, or less, thirty of alum, thirty-five of chloride of sodium, and one hundred of minium, or other oxide of lead, yield a white enamel when the fluxes do not predominate too much; and a gelatinous glass when the latter are in large quantity. This glass is good for red, and the enamel does for all clays, or earths, which can stand a strong fire.

It is very important to observe, and to be aware of the fact, that the sand which is used for enamels is not that which contains only silicic acid—this is worth nothing—it must be a sand having also talc.

It requires nearly one part of talc to three of silicious sand to make enamels, and color fluxes, *et cetera.*

What appears to be most essential for the success of enamels is the choice of the sand. It is very possible to compose the sand by art. Although CLOUET did not decompose it, he found by synthesis that three parts of suitable sand and one part of talc were very good for enamels; hence it is obvious that one requires only a good analysis of the talc to be able to compose the mixture easily. This sand will be procured in places where earthenware is made. It is easily known; independently of the silica which constitutes the greater part of it, talcky particles are found in it in great quantity, and, to be good, it must involve about one-fourth; when it does not contain enough, the enamel which it produces is more difficult to melt, and does not become smooth; it remains grainy, and makes what is called *egg-shell.* Combinations of earth certainly exist capable of producing very good fluxes either for enamels or for transparent colors. It would be desirable to try these combinations. Heavy spar—sulphate of baryta—and lime melt very well together. By adding a little silica and a little magnesia, it is probable that one would produce a very good substance. If this glass, composed of lime and baryta only, were solid enough to resist the air and weak acids, one would not require to add silica to it; but if, as CLOUET thinks, chloride of sodium must also enter into the composition of these glasses, then silica must be there also. One might vary experiments on the subject. When glasses destined for color fluxes are employed, it is customary, in order to render them still more fusible, to add to them a little nitrate of soda and borax.

It is essential that the lead and tin destined to make the oxide for producing the white enamel be melted and mixed together before being calcined; and if it be desired that the enamel have all its whiteness immediately, it is good that this calcination should be very complete.

CLOUET suggests that bismuth might be substituted for the lead. This alloy would give a good product. Bismuth might also be added with lead, making the following mixture—namely, one part of lead, one of bismuth, one of tin, or using other proportions.

The principal characteristic of a good enamel, and which renders it fitted to be laid on baked clays, earths, or metals, is its facility in glazing with a moderate fire—a cherry-red heat, or a little more or less, according to the nature of the enamel—without entering into complete fusion. These are the qualities possessed by enamels which are applied on pottery or earthenware articles. They do not enter into complete fusion, otherwise they fail; they take only a pasty state—indeed, a very firm paste; and yet, when they are baked, one would say they had been completely melted.

There are two modes of painting on enamels—on the crude, or on the baked. One employs, or may employ, for the same object both of these methods. Solid colors may be laid on which can stand the fire necessary for baking, in melting the crude enamel, and afterwards finish with delicate colors. The hues which are laid on the crude enamel do not require a flux; there is one, however, to which silica must be added—namely, the calcine of copper, which gives a very fine green; but when it is wished to employ it on the crude enamel, it must be mixed with about two parts by weight of silica, and the heat raised till the mixture enters into combination. The mass obtained is afterwards pulverized for use.

It is also essential, in order to have the enamel very white, to make sure of the purity of the lead and tin. If these metals contain copper or antimony, as pretty often happens, the enamel will not be fine. Iron is less hurtful.

COLORED ENAMELS.—All the colors are produced with metallic oxides. These are more or less fixed in the fire, according as they hold more or less strongly to their oxygen; thus, all the metals which easily lose this element cannot stand a great degree of heat, and cannot be employed on the crude enamel.

Purple.—This color is oxide of gold, which can be prepared in different manners, either by precipitating with tin, or by the chloride of tin, a solution of gold much diluted with water. One must put only as little as possible of the stannic solution to form this deposit; it is added gradually till the purplish color appears, then no more is added, and the color is left to deposit, and afterwards poured into a glass vessel to dry it slowly. The different solutions of gold, in whatever manner precipitated, provided the gold is thrown down in the state of oxide, give always a purple hue—so much the finer the purer the oxide; however, neither the copper nor the silver, which usually exist alloyed with the gold, spoil this tint very perceptibly. Iron changes it; but the precipitate of gold which gives the finest purple is, without contradiction, fulminating gold, which loses this property when it is mixed with fluxes. Purple is a powerful color; it can bear much flux, and in small quantity imparts its color to much matter.

It appears that the saline fluxes agree better with it than those into which the metallic calcines enter; thus it will be necessary to give it those which are made with silica, carbonate of lime, and borax; or white glass, borax, a little white oxide of antimony, and nitrate of soda. Purple can bear, or carry, from four to twenty parts, and even more, of flux, according to the shade desired. Painters on enamels usually employ for purple a flux which they name *brilliant white*; this appears to be a semi-opaque white enamel, which is put on tubes, and afterwards blown into bulbs at the enameller's lamp. These bulbs are afterwards broken, so that this flux is found in commerce in small scales, which have the appearance of *debris* of minute hollow spheres. Painters in enamel mix this flux with a little nitrate of soda and borax. Purple does not stand a strong fire.

Red.—There is no metallic oxide which yields directly a melted red—that is to say, no metallic calcine, entering into fusion, and combining in the form of transparent glass with the fluxes of glasses, gives directly a red color; to obtain this, it must be compounded of different substances in the following manner:—Two, or two and a half, parts are taken—or even one may be sufficient—of sulphate of iron, and one of sulphate of alumina; they are melted together in their water of crystallization, and care is taken to mix them well; they are heated to perfect dryness; the fire is then increased till the mixture becomes red. This last operation should be performed in a reverberatory furnace. The red mixture is kept on till it assumes throughout a uniform tint, which is seen by withdrawing it a little from time to time, and letting it cool in the air. One then sees if the matter be sufficiently red. It must be left to cool to judge of this, because it appears black so long as it is hot. The sesquioxide of iron gives a red hue very well, but it is fugitive; for as soon as the oxide of iron enters into fusion, the portion of oxygen which gives it its red tinge quits it, and it becomes black, yellow, or greenish. Thus, to preserve the red color of this oxide in the fire, it must be prevented from vitrifying and giving up its oxygen.

CLOUET tried many different substances to procure this fixity for it; alum alone succeeded: the proportions of alum and sulphate of iron may be varied; the more alum that is present, the paler does the color become. Three parts of alum to one of sulphate of iron give a tint which approaches to flesh-color. Alum also renders this hue fixed in a pretty strong fire; this tinge may be employed on the crude enamel; it is much more persistent than purple, but yet not so much so as cobalt-blue. It may be washed to take away the superfluous saline matter; but it may also be employed without being edulcorated; it is even more fixed in this state and finer: it does not require much flux; the flux composed of alum, minium, chloride of sodium, and enamel sand, appears to suit it best. This mixture is compounded in such a manner as to render it sufficiently fusible for its object; from two to three parts of it are mixed with the color. In general, one usually takes three parts of flux to one of color; but this proportion may and ought to vary according to the nature of the hue and the shade desired. The red calcine of iron, quite alone, when it enters into fusion with the glasses, gives a tint which appears black; if this be diffused over a sufficient quantity of glass, it becomes at last a transparent yellow. Thus the tint which is really given by the iron combined with the glasses is a yellow one; but which, being concentrated, becomes so deep that it appears black. In the process indicated above to make the red color, the oxide of iron does not melt, *and this is the essential point;* for if this color is heated till it vitrifies, it becomes black or yellow, and disappears if the coating is thin, and the oxide of iron is in small quantity.

Yellow.—Although this color may be obtained directly, compound yellows are preferred, because they are of surer and easier use than the hue which may be obtained directly from the silver.

The compound yellows are obtained according to the same principles as the red color from iron: to obtain these hues metallic oxides are employed, the complete vitrification of which is prevented by mixing them with other substances, such as refractory earths or metallic oxides difficult of fusion.

The metallic mixtures which constitute the base of the yellows are usually those of lead, minium, white-lead, or litharge; an alkaline antimoniate is also used. The following are the different compositions practised: One part of white oxide of antimony, one of carbonate of lead, or two or three parts—these proportions are very variable—one part of alum, and one part of ammoniacal salt; all these matters are pulverized and mixed well together; then they are put into a vessel on a fire sufficient to sublime and decompose the ammoniacal salt; and the operation is finished when the matter has taken a fine yellow color. The oxide of lead mixed, in small quantity, either with silica or alumina, also with pure oxides of tin, very white, gives likewise yellows; one part of oxide of lead is put to two, three, or four of the other above-mentioned substances.

One may also take for these different yellow compositions, oxide of iron. Different shades of yellow are then obtained, and these may be varied to any desired extent.

The yellows require a little flux; one part or two usually suffice: the saline fluxes do not agree with them, especially those into which nitrate of soda enters. They must be used with fluxes composed of enamel sand, oxide of lead, and borax, suppressing the chloride of sodium. A yellow may also be drawn directly from oxide of silver—the best way of using which is to employ it pure; then one tints, not paints with it; it is sufficient to put a slight film of it in the place to be colored, and heat the article slightly to give it the hue; the fire must not be too strong; the proper degree will be easily found. When the article has been heated to the point necessary, it is withdrawn from the fire, and the coating of oxide of silver which has been put on, and which should be found reduced to a regulus, is taken off; then the place which it occupies is seen to be tinged a very fine yellow, and having no thickness. It is chiefly on transparent glasses that this process succeeds best; very fine silver filings produce also this effect. The sulphate of silver succeeds very well, pounded with a little water to lay it on evenly. As the pellicle of silver which covers the color has to be removed, it is requisite to avoid fixing the film with fluxes; and it ought, therefore, to be applied after the fusion of the rest, for, as it is very fusible and easily changed, it would deteriorate with the other colors; and as the coating of silver which is reduced must be taken off, the fluxes would fix it, and it could not be removed. This annoyance does not take place with glass, for the silver yellow is laid on the opposite sides from the other colors.

Green Enamel.—It is known that a green color may be produced by a mixture of yellow and blue; but recourse is seldom had to this practice for enamels, as they can be obtained of this color almost always directly with the oxide of copper, or still better with the oxide of chromium, which has the advantage of resisting a strong heat.

There are two oxides of copper—the oxide, which is blue in the state of hydrate, but blackish-brown when dry, and it colors green all the vitreous combinations into which it enters; and the suboxide, of a reddish color, which communicates this to enamels, but it is very fugacious. The oxide requires, at most, one or two proportions of flux, either saline or metallic, to enter into complete fusion; but a much smaller dose is commonly taken, and a little oxide of iron is introduced. To four pounds of frit, for instance, two ounces of oxide of copper and forty-eight grains of sesquioxide of iron are used; and the ordinary measures are pursued for making very homogeneous enamel.

The green produced by the oxide of chromium is much more solid; it is not affected by a powerful fire, but is not always of a fine shade. It generally inclines too much to the dead-leaf yellow, which depends on the degree of oxidation of the chromium.

Red Enamel.—It has just been stated that suboxide of copper affords a fine red color when it can be fixed, a result difficult to obtain on account of its fugitive nature; slight variations of temperature enabling it to absorb more oxygen. The proper point of fusion must be seized, for taking it from the fire whenever the desired hue is brought out; but, when a high temperature has produced a greater degree of oxidation, this may be corrected by adding some combustible deoxidizing matter, as charcoal, tallow, tartar, *et cetera.*

The copper then returns to its minimum of oxidation, and the red color which had vanished reappears. It is possible in this way, and by pushing the heat a little, to accomplish the complete reduction of a part of the oxide; and the particles of metallic copper thereby disseminated in a reddish ground, give this enamel the aspect of the stone called *avanturin.* The easiest and most certain method of procuring suboxide of copper is to boil a solution of equal parts of sugar and sulphate, or rather acetate, of copper, in four parts of water. The sugar takes possession of a portion of the oxygen of the cupreous oxide, and reduces it to the suboxide, when it may be precipitated in the form of a granular powder of a brilliant red. After about two hours of moderate ebullition, the liquid is set aside to settle; the precipitate, decanted off, is washed and exsiccated. The annexed equation represents the decomposition :—

$$\underbrace{48\,CuO}_{\text{Oxide of copper.}} + \underbrace{C_{12}H_{12}O_{12}}_{\text{Sugar.}} = \underbrace{24\,Cu_2O}_{\text{Suboxide of copper.}} + \underbrace{12\,CO_2}_{\text{Carbonic acid.}} + \underbrace{12\,HO}_{\text{Water.}}$$

Pure red oxide, properly employed by itself, furnishes a hue which vies with the finest carmin, and by its means every tint may be obtained from red to orange, by adding a greater or smaller quantity of sesquioxide of iron.

The preparations of gold, and particularly the oxide and purple of Cassius, are likewise employed with advantage to color enamel red, and this composition resists a powerful fire tolerably well.

For some time back, solutions of gold, silver, and platinum have been used with success instead of their oxides; and, in this way, a more intimate mixture may be procured, and, consequently, more homogeneous tints.

Blue Enamel.—This fine color is almost always obtained from the oxide of cobalt or some of its combinations, and these produce it with such intensity that only a very little can be used, lest the shade should pass into black. The cobalt blue is so rich and lively that it predominates in some measure over every other color, and masks many so that they can hardly be perceived; it is also most easily obtained. To bring it out, however, in all its beauty, the other tints must be removed as much as possible, and the cobalt itself should be tolerably pure. This metal is associated in the best known ores with a considerable number of foreign substances, as iron, arsenic, copper, nickel, and sulphur, and it is difficult to separate them completely; but for enamel blues, the oxide of cobalt does not require to be perfectly free from all foreign metals; the iron, nickel, and copper, being most prejudicial, should be carefully eliminated. This object may be most easily attained by dissolving the ore in nitric acid, evaporating the solution to a sirupy consistence, to expel the excess of acid and separate a portion of arsenic. It is now diluted with water, and a solution of carbonate of soda is dropped slowly into it with brisk agitation, till the precipitate, which is at first of a whitish-grey, begins to turn of a rose-red. Whenever this color appears, the whole must be thrown on a filter, and the liquid which passes through must be treated with more of the carbonate of soda, in order to obtain the arseniate of cobalt, which is nearly pure. Since arsenic acid and its derivatives are not capable of communicating color themselves, and as they moreover are volatile, they cannot impair the beauty of the blue, and hence this preparation affords it in great perfection.

Metallic fluxes are not the most suitable for this tint, because they always communicate a tinge of greater or less intensity, which never fails to injure the purity of the blue. Nitrate of soda is a useful addition, as it keeps the oxide at the maximum of oxidation, in which state it produces the richest color.

Black Enamel.—Black enamels are made with binoxide of manganese or protoxide of iron; to which more depth of color is given with a little cobalt. Clay alone melted with about a third of its weight of protoxide of iron, gives, according to Clouet, a fine black enamel.

Violet Enamel.—The binoxide of manganese, in small quantity by itself, furnishes, with saline or alkaline fluxes, an enamel of a very fine violet hue; and variations of shade are easily had by modifying the proportions of the elements of the colored frit. The great point is to maintain the manganese in the state of binoxide—$Mn\,O_2$—and, consequently, to beware of placing the enamel in contact with any substance attractive of oxygen.

Such are the principal colored enamels hitherto obtained by means of metallic oxides; but since the number of these oxides is increasing every day, it is to be wished that new trials be made with such as have not yet been employed. From such researches some interesting results would unquestionably be derived.

Enamelling of Watch-Dials.—The following is the process for enamelling watch-dials, altered from the *Cyclopedia of Useful Arts:*—

The *dies*, as they are called—consisting of circular plates of brass, of one-twentieth of an inch in thickness—having been moulded to the proper shape, cut to the required size, the feet affixed, *et cetera*, are cleansed in a dilute solution of nitric acid, then washed in clean water with a soft brush and a little white sand, and being quite free from the scales formed on their surfaces during their previous heating with the blowpipe, they are ready for the enamelling.

The tools used for this purpose are—1. An agate mortar and pestle to grind the enamel. 2. A small riveting hammer. 3. A flat spatula, seven-eighths of an inch broad, and a little stronger than those used for paint knives. 4. A spatula of good steel, rather thicker than the last, but of equal breadth; one side of this is flat, and the other a little curved. It is used to spread the hard enamel on the copper. 5. A spatula for spreading the hard enamel on the under side of the copper: this is called the bottom spatula; it is similar to the former, but broader at the end. 6. A quill, cut like a toothpick, for clearing the enamel out of the centre holes of the dials. 7. Two damask napkins for drying the water from the enamels. 8. A small basin with a cover to hold the enamel used for the tops of the dial-plates. 9. A gallipot to contain the enamel for the bottoms. 10. A cylindrical block of wood upon which the copper is fixed, when ready for the laying on of the top enamel. This, for common-sized plates, may be one and a half inch in diameter, and six inches long. Soft wax is fixed at one end of this, so as to form a kind of cap to the block. 11. A box, or tray, to hold the plates when the enamel is spread on them. It may be about sixteen inches long, nine broad, and one and a half deep. 12. A small steel anvil on which to break the enamel. The face is generally about an inch in diameter.

The soft glass enamel is bought by the enameller in cakes, and to prepare it for use it is first broken up with the riveting face of the hammer, any parts colored with red or black streaks being rejected, as they would contaminate the whole. When broken into fragments not larger than small peas, it is carefully ground with water in the agate mortar, and the fine powder, into which it is gradually reduced, is washed away four or five times during the grinding by filling the mortar with clean water, and agitating the enamel with the broad flat spatula, stirring it up from the bottom till the water appears quite milky: the enamel should be allowed to settle to the bottom, and the water poured off. Specks of dirt must be carefully removed, as these will make their appearance on the surface of the dial-plates. The enamel should be reduced to the fineness of fine grain gunpowder; although for some purposes it may be as coarse as maw-seed. After sufficiently grinding, and washing away the flour, the enamel is kept under water in the covered basin until required for use.

For bottoms, the Venetian hard enamel is used; it is broken up with the hammer, and then crushed in a cylindrical iron mortar, with a pestle fitting into it. When pounded until as fine as the glass enamel, it is ground in the agate mortar to an almost impalpable powder; but this enamel is not to be washed, as in this case the flour is of value. It is then kept under water ready for use; for if allowed to get dry after being ground, it must be worked up again in the agate mortar, otherwise it is likely to blister in the fire.

Care must be taken in selecting the Venetian hard enamel, such as is to be used for the faces or tops of dial-plates, so that the color may be pure. To prepare it, it is heated to redness on a piece of platinum in an enameller's muffle, and then suddenly quenched in very clean spring water, which causes it to split up into very small pieces; these are ground up in the agate mortar. The enamel is broken up in this way, to avoid the use of the hammer and steel pestle; because, if a small particle of steel gets into the enamel, it will be productive of mischief. The flour separated during the washings is allowed to subside, and is added to the gallipot with that which is used as bottoms. When the enamel is ground sufficiently fine, it is kept covered with strong nitric acid in a wide-mouthed stoppered glass bottle.

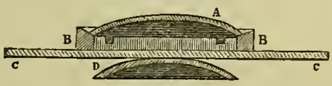
In enamelling with soft glass enamel, a napkin four times doubled is laid on the workboard: the copper is to be held in the left hand with the feet upwards, and a small quantity of the hard enamel for bottoms is taken out of the gallipot on the end of the bottom spatula and spread roughly on the copper, covering it closely up to the feet and centre holes. It is then laid between the folds of the cloth till a little water is absorbed, when the enamel must be extended, as uniformly as possible, with the convex side of the spatula. It must then be more smoothly spread by again drying it with the napkin, and spreading it with the spatula, pressing more lightly as the enamel gets dry. The operation of laying the bottom is then completed by clearing the centre hole with the quill.

A clean napkin is next folded and placed on the board, so as to hang over the edge about three or four inches, a weight being put upon it, to prevent its being dragged down. When the wax upon the laying block has been softened and made of a shape fit to receive the copper, the latter must be placed evenly on, and the feet pressed into the wax, till the enamelled undersurface of the copper nearly touches it. A better method, however, is to place the setting block upon the copper and press it down; for in this way the shape of the copper is preserved, and the upper side secured from the perspiration of the hands, which might cause the enamel to blister. A soft hair-brush, or a hare's foot, is then applied to clean the copper, taking care not to leave any of the hard enamel on the surface or about the edge. A small quantity of the glass enamel is now to be taken upon the end of a flat spatula, and laid upon the copper near the centre hole, being careful not to allow any water to pass through the latter, as that would take away the enamel from the bottom, which could not be replaced without injuring the enamel on the top, the two kinds thus getting mixed, and both being spoiled. When enough of the glass enamel has been put upon the copper, it must be roughly spread, by repeatedly indenting the edge of the flat spatula into the paste, crossing it in all directions till it lies of a uniform thickness. The inequalities thus formed on the surface are reduced by simply tapping the side of the block two or three times with the edge of the spatula, and the side or part of the enamel which is too thick, must be reduced by removing a portion of it to places that appear deficient. This is done by spreading the spatula over the enamel, turning the block round with the fingers and thumb of the left hand, till it lies generally even. The napkin is then again applied, and the surface made smoother by passing the spatula over it in all directions, bearing a little harder on the enamel as it gets drier. As the moisture attracted to the surface by this rubbing and spreading of the enamel would prevent the enamel from lying smoothly, it must be dried again and laid by, passing the spatula lightly over it. In determining the thickness of the enamel, allowance must be made for its more bulky granulated state previous to melting. In enamelling the tops of convex plates, the *shoulder*, which is about one quarter of the distance from the edge to the centre, should be laid somewhat thicker than towards the edge; because the latter being lower than the centre, the enamel, when in a fluid state in the fire, will flow down towards it, and thus produce an inequality of thickness on all parts of the copper. When the copper is covered, it must be carefully removed from the block by gently raising it with the back of the thumb-nail, under the edge, and as near each of the feet as possible. It is then to be placed in the covered tray, and kept free from dust, till wanted for firing.

In hard enamelling, the copper, made chemically clean, is fixed on the laying-block as before, and a coat of soft enamel first laid on, about two-thirds of the thickness applied in soft enamelling. This must be fired till the enamel is melted down to a tolerably smooth surface, and when cold, should any specks of dirt appear, they must be cut out with the point of a square graver whetted to a very obtuse angle. The next operation is to put the plate for a short time into dilute nitric acid, just strong enough to cleanse the scale from the edge of the copper; it must then be washed in clean water, and fixed on the laying-block, the wax being made soft enough to admit the feet without any great pressure. A small quantity of hard enamel, thoroughly purified of the acid by repeated edulcoration, must now be equally spread over the whole surface of the plate, and the corner of a clean napkin laid upon it to absorb a portion of the water. The enamel can then be distributed more evenly over the surface of the plate; when nearly smooth and of uniform thickness, it must be dried again, and the spreading renewed for about ten minutes, rubbing it in every direction till it is compressed as closely as possible.

Firing is the next process, by which the enamel is melted into a uniform vitreous mass on the surface of the copper. A ring is used for supporting the edge of the dial while in the fire, so that the feet may not come in contact with any substance, or they would be loosened. These rings are made of one part pipe-clay and two parts of black-lead. To prevent the adhesion of the enamel to the ring, one part of the ring is made like the frustrum of a very obtuse-angled hollow cone, while the other side forms a plane perpendicular to the sides of the cylindrical parts. The dial, being laid in the hollow side, will just touch it at the part where the copper is exposed, and thus prevent the adhesion of the enamel, especially if this part of the ring be first rubbed with fine whitening. When the dial is placed on the ring, both are set on a flat circular stone or a slab of Stourbridge clay; and as the dial must be kept turning in the fire during the whole time of melting, so as to be equally heated, the slab, with the ring and dial upon it, are set upon a small piece of clay, moulded into the segment of a sphere five inches in diameter. The enamellers call this arrangement a *turner:* it is shown in section in Fig. 444, where A represents a convex dial for a watch without a brass edge; B, the ring; C, the slab or *planch*, and D, the turner.

Fig. 444.



When the furnace is sufficiently heated, the enamelled plates must be laid upon the hearth on a ring of proper size, and there left until the moisture is entirely evaporated. The planch, having been raised to nearly a white heat in the fire, is withdrawn, and the plate and ring set on it, as nearly as possible in the centre, when the whole is to be placed on the turner under the muffle, and kept in motion until the enamel assumes one uniform surface. It must then be withdrawn with the tongs, and another treated in the same way, till the whole day's work is fired: this may vary from three to six dozen plates.

A plate will seldom come out of the fire free from black or green specks. The union of so many small particles will also produce an unpleasant mottled appearance. The specks must be removed with a square graver; and as the centre hole of the copper and also the edge will appear to rise above the surface of the enamel, these are to be carefully filed down, and the plate is then ready for *using off;* that is, rubbing the surface on a gritstone with fine sand and water until the glazed surface is removed, and a uniform rough surface is produced. This removes the mottled appearance, and gives a more equal convexity to the plate. It also takes away the semi-transparent appearance of the enamel, and greatly increases its intense whiteness and beautiful opacity. After the using off, the plates are subjected to the action of a stiff hair-brush and wet sand, then washed in clean water and dried. They are now ready for the finishing fire.

The holes left in picking out the specks are filled up with the finest enamel, almost as fine as flour, and the plate being placed in a proper-sized ring, is set on the iron hearth of the furnace, gradually bringing it nearer the fire until it attains such a heat as will permit it to be placed in the hottest part without danger of cracking. The ring and plate are then lifted upon the planch with the tongs, and kept in motion until a white heat is attained. This being done, it must be taken out of the fire, breathed upon for a few seconds, and immediately returned to the heat: this will bring out a beautiful glass, and a degree of whiteness not hitherto attained by any other means. The proper effect being produced, the plate must be withdrawn and set to cool gradually. If free from specks, the plate is ready for the next process; if specks exist, they can only be removed with the graver—omitting the using off—and the firing must be repeated.

In firing hard enamel dials, the heat must not be so great, and the plate must be taken from the fire as soon as the enamel is found to form a tolerably compact body.

The hours, *et cetera*, are painted on the dial in a soft black enamel prepared for the purpose. It is ground very fine in an agate mortar, and mixed with oil of lavender until sufficiently diluted. A mark is made on the dial to indicate the place of the numeral XII. Then, with the assistance of a division plate and its index, the divisions are slightly traced from the centre with a black-lead pencil. The circular lines which contain the indications of the hours, minutes, *et cetera*, are previously traced with compasses, one point of which is furnished with a cone, and the other with a port-crayon and pencil. When the painting is perfectly dry, the dial is once more fired.

In ornamental enamelling, when the enamel is not intended to cover the whole surface of the plate, it is necessary to form a lodgment for it. The outlines of the design are therefore first drawn upon the plate, and then traced with a graver. The spaces enclosed within the outline of the design must next be deepened by proper tools, equal to the height which would have been given by the ridge or border, had the plate been intended to have been enamelled all over. This deepening is effected with a flat graver, and it must everywhere be of equal depth; for if any shallower portions remain, the enamel falls away, or is so thin in those parts as to show the metal through. The bottom of the lodgments for the enamel must be slightly hatched or roughened with the end of a small riffler file, broken square across, for the purpose of affording a hold to the enamel.

The plate is then thoroughly cleaned, and is next covered with a coat of white enamel laid upon it wetted with water, much skill being required to bring the enamel into contact with the ridges or borders of the design.

In some cases, the design is produced by stamping a steel die upon a gold strip, and the indentations thereby produced are filled up with differently-colored enamels by means of a steel point. This method calls for the display of much skill and taste on the part of the enamelle The enamels are mixed with water or with oil of lavender, according to circumstances; several layers are usually applied, the object being fired after each application.—*Tomlinson.*

Enamelling on Iron and other Metals.—Enamelling of iron for culinary and other utensils, has of late years become a very extensive trade; and the Editor does not wonder at this, for the articles produced are excellent, and will, no doubt, before long come into general use for all ordinary house services. The glazed dishes or basins are also most desirable in the laboratory, and can be employed in nearly all processes of digesting, *et cetera.* Glazed pipes are a great boon, in many instances, as the following proves:—Some time ago, the Editor analysed a sample of water passing through lead pipes in the house of an influential gentleman in the neighborhood of Liverpool. The water was *actually poisoned with the metal.* The family were constantly ill, and *when they left home always became better.* The medical man attending them suspected that there must have been something the matter with the water, and the analysis showed he was right in his surmise. The Editor recommended the lead pipes to be removed, and glazed pipes erected in their stead. The result has been most satisfactory, and no more inconvenience has been experienced.

The enamelling is the patent process of CHARLES HENRY PARIS of France; and his invention, which is largely and most successfully carried out, as far as regards culinary utensils, by Messrs. T. F. GRIFFITHS and COMPANY, an enterprising firm in Birmingham, consists in certain means of coating articles made of wrought-iron with glass or vitreous matter, so as to keep off the atmosphere and other fluids and matters, which would cause an oxidation of the metal. In order that the invention may be most fully comprehended, and readily carried into effect, the Editor proceeds to describe the mode pursued. Articles made of sheet or of wrought iron, whether in the form of vessels, trays, pipes, or otherwise, are first to have their surfaces cleansed, which PARIS prefers to be done by dilute acid, as is well understood, and dried; then a coating of gum-arabic, dissolved in water, is to be applied to the surface by a brush, or otherwise; then by means of a sieve, the fine powder of glass or vitreous matter is to be sifted all over the surfaces. The article is then to be introduced into an oven heated to 212° to 300° Fahr. to be exsiccated; and, when dry, it is to be removed into another chamber, and elevated to a bright red heat till the glass or vitreous matter is melted on the surface, which will readily be seen by looking through a hole in the cover of the recipient. The articles are then to be removed into a close chamber, with a cover to exclude as much as possible the action of the air, till the whole is cooled down. If, on examination, the coating is imperfect, another is to be added in like manner to the first.

The following is the vitreous mixture preferred by the patentee:—One hundred and thirty parts of flint glass reduced to powder, twenty and a half parts of carbonate of soda, and twelve parts of boracic acid. These matters being intimately mixed, are to be placed in a glassmaker's crucible, melted, then drawn off, cooled, reduced to an impalpable powder, which is to be sifted through a fine sieve—say about sixty holes to the inch—and this powder is to be applied in the dry state as before described. It is important, in preparing the glass or vitreous substance, that it should be free from foreign impurities; for this reason, steel stampers are employed for crushing the matters into a powder, and before employing the crucible, Paris causes it to be coated with glass, by applying gum-water to its inner surface, and then dusting over the powder of glass; and, after the same has been well dried, heating gradually up to the point of fusion of the glass, by which the surface of the crucible will be coated, and will thus, when used, prevent impurities from the crucible getting mixed up with the glass or vitreous mixture. If it be desired that the surfaces of the iron should have colored glass or vitreous matter applied thereto, then, the patentee states, it is first to be coated with the mixture above named, and afterwards a further coating of colored glass is applied to the surfaces, as may be desired. Messrs. Griffiths have succeeded in printing colored designs upon the enamelled wares, and they produce upon a variety of articles a very good effect.

Enamelling on other metals, says Ballantyne, is generally performed on plates of gold or of copper, but seldom on silver, as it is apt to occasion flaws in the surface of the enamel. Copper is the metal most generally used for this purpose, coated with the white enamel, on which painting is executed with colors which are melted in the fire, where they take a brightness and lustre like that of glass. This kind of painting is particularly prized for its peculiar brilliancy and vivacity, which is permanent, the force of its hues not being liable to be effaced or sullied by time, as in other painting, and continuing always as fresh as when it came out of the workman's hands. This method of painting is almost entirely confined to miniature; larger works being liable to certain accidents in the operation. The most perfect kind of enamelling is practised on plates of gold, the other metals being less pure. Copper, for instance, sometimes scales with the application; and silver turns the yellow white. To obviate the cracking of the enamel, the plates are generally made a little round or oval, and rather thin. The operation is usually commenced by laying on a couch of white enamel on both sides of the plate, which prevents the metal from swelling and blistering; and this first layer serves for the ground of all the other tints. The next step is to draw out exactly the subject to be painted, with basic sulphate of the sesquioxide of iron, mixed with foreign oil of lavender, marking all parts of the design very lightly with a pencil. After this, the colors —very finely ground, and mixed with the oil, somewhat thick—are to be laid on, attention being given to the mixtures and colors which agree to the different parts of the subject; for which purpose it is necessary to understand painting in miniature.

When the colors are all laid, the painting is to be gently dried over a slow fire to evaporate the oil, and the colors are afterwards melted to incorporate them with the enamel, making the plate red hot in a fire such as enamellers use. Afterwards, the painting may be retouched, and is then to be committed a second time to the fire, and so on till the work be completed.—*Encyclopedia Britannica.*

Enamelling at the Lamp.—The art of the lamp enameller, says Ure, is one of the most agreeable and amusing. There is hardly a subject in enamel which may not be executed by the lamp flame in very little time, and more or less perfectly according to the dexterity of the artist, and his acquaintance with the principles of modelling. In working at the lamp, tubes and rods of glass and enamel must be provided of all sizes and colors. The enamelling table is represented in Fig. 445, round which several workmen with their lamps may be placed, while the large double bellows, D, are set a-blowing by a treadle moved with the foot. The flame of the lamp, when thus impelled by a powerful jet of air, acquires surprising intensity. The bent nozzles or tubes, A A A A, are made of glass, and are drawn to points modified to the purpose of the enameller. Fig. 446 shows in perspective the lamp, A, of the enameller standing in its cistern, B; the blowpipe, C, is seen projecting its flame obliquely upwards. The blowpipe is adjustable in an elastic cork, D, which fills up exactly the hole of the table into which it enters. When only one person is to work at the table provided with several lamps, he sits down at the same side with the pedal of the bellows; he takes out the other blowpipes, and plugs the holes in the table with solid corks. The lamp is made of copper or tinplate, the wick of cotton threads, and either tallow or oil may be used. Between the lamp and the workman a small board or sheet of white iron, B, called the screen, is interposed to protect his eyes from the glare of light. The screen

Fig. 445.

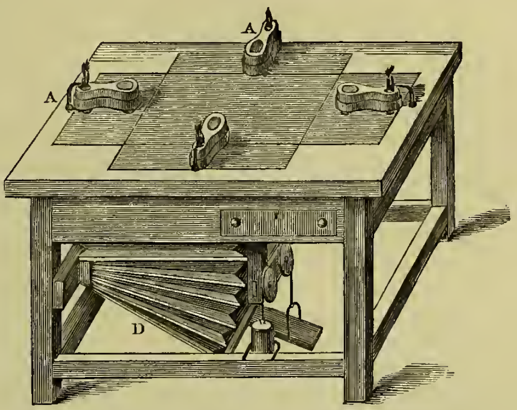
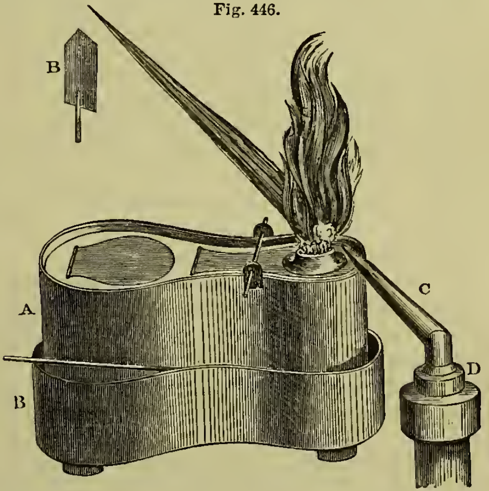


Fig. 446.



is fastened to the table by a wooden stem, and it throws its shadow on his face. The enamelling workshop ought to admit little or no daylight, otherwise the artist, not perceiving his flame distinctly, would be apt to commit mistakes. It is impossible to describe all the manipulations of this ingenious art, over which taste and dexterity so entirely preside. But the following may serve as an example:—Suppose the enameller wishes to make a swan. He takes a tube of white enamel, seals one of its ends hermetically at his lamp, and while the matter is sufficiently hot, he blows on it a minikin flask, resembling the body of the bird; he draws out and gracefully bends the neck; he shapes the head, the beak, and the tail; then, with slender enamel rods of a proper color, he makes the eyes; he next opens up the beak with pointed scissors; he forms the wings and the legs, finally attaching the toes: the bird stands complete. The enameller also makes artificial eyes for human beings, imitating so perfectly the colors of the sound eye of any individual, as to render it difficult to discover that he has a blind and a seeing one.

It is difficult to make large objects at the blowpipe; those which surpass five or six inches become nearly unmanageable by the most expert workmen.— *Ure.*

ETHER.—*Ether*, French; *Æther*, German.—The liquid generally so called—sulphuric ether—is said to have been known to Raymond Lully, who lived in the thirteenth century. The method of making it is described in the dispensatory of Valerius Cordus, from which Conrad Gesner transcribed it into his *Thesaurus Euonymi de Remediis Secretis*, published in 1552, where it is called *Oleum Vitrioli dulce.* Basil Valentine and Paracelsus appear to have been acquainted with ether, though not in a state of purity. Boyle mentions this compound, but he nowhere alludes to it minutely. It was Dr. Frobenius, in 1730, who first drew the attention of chemists to this curious liquor, and he described several of its properties. In his paper it was first called *ether*, for the Germans long distinguished it by the name of *naphtha.*

In modern chemistry, ether is the term given to a class of very light, volatile, inflammable, and fragrant spiritous liquids, obtained by distilling in a retort a mixture of alcohol with almost any acid. Every one modifies the result in a certain degree, whence several varieties of ether are produced. This compound is found in nature in small quantity, not uncombined, but in conjunction with acids, forming neutral ethers. The flavor of the pine-apple, melon, and various other fruits, depends on the presence of these.

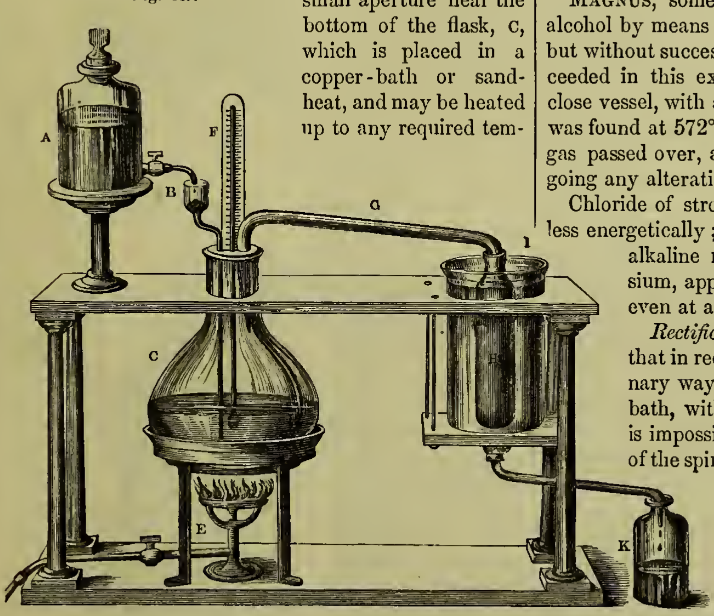
Ether.—*Sulphuric Ether—Oxide of Ethyl.* This compound, being the only ether of commercial importance, will be described at some length. It is generally obtained either by distilling a mixture of sulphuric acid and alcohol, or by permitting the latter to dribble into the heated and somewhat weak acid. Phillips gives the following directions for the former process:—To sixteen ounces of sulphuric acid add the same quantity of rectified spirit, and distil over about ten fluid ounces; or continue the operation until the contents of the retort begin to rise, or the residual liquor becomes considerably sulphurous; mix the two products, and if a light and heavy fluid appear, separate them; add potassa to the former, as long as it dissolves; separate the ether from the alkaline solution, and distil about nine-tenths of it, which may be preserved for use. It will have a specific gravity of 0·75. Preparing ether upon a larger scale, it was found that fourteen parts of alcohol—specific gravity 0·820—mixed with the same quantity of sulphuric acid—density 1·80—and submitted to distillation, yielded about eight parts of an impure product—specific gravity 0·770. Seven parts of alcohol were then added to the residuum, and nearly eight parts more of impure ether drawn over. These distillates, when mixed, had a density of about 0·782, and when rectified by distillation over carbonate of potassa, afforded ten parts of ether, having a specific gravity of 0·735, and about three and a half parts of ethereal spirit, which was employed, instead of an equal quantity of alcohol, in the succeeding operation.

Boullay's method for the production of ether, which is an improvement upon the preceding, is as follows:—Equal parts of sulphuric acid and of alcohol are cautiously mixed in a retort, connected with a tubulated receiver by means of a condensing adapter; the retort is placed in a sand-heat, and the receiver cooled by the proper application of water. An S tube passes air-tight through the tubulure of the retort, the lower end of which is drawn out into a very small or almost capillary opening, and so adjusted as to dip to about two-thirds of the depth of the liquid in the retort; heat is applied till the contents just begin to appear to seethe; the fire is then slackened, or damped, so as to keep up a regular ebullition, and as the apparatus is air-tight, the expansion within is suffered to escape by a siphon tube, which passes through the tubulure of the receiver. When about two parts have passed over, an equal quantity of alcohol is suffered to trickle into the retort by the S tube, so gradually as not to check the boiling, but to compensate for that which distils over. When in this way a quantity of alcohol has been added, equal to that contained in the original mixture, the operation is generally left to itself, and as soon as white vapors and drops of oil appear in the adapter, the fire is withdrawn. The products of this distillation are usually divided into three parts: the first is alcohol with a little ether, which first passes over; the second, and largest, or ethereal portion, is mixed with a sixteenth of its weight of carbonate of potassa, which abstracts water and sulphurous acid, and decomposes any oil of wine—sulphide of ethyryl—that may chance to be contained in it; this mixture is shaken, and when the ether has acquired a sweet and pure odor, it is rectified by slow distillation from a water-bath, till two-thirds of its original bulk are drawn over; the distillate is pure ether. The residue of the rectification is mixed with the last portion of the original distillation, and kept for some days in contact with the alkaline carbonate before used, and a little water and binoxide of manganese are added, so as to oxidize the sulphurous acid; when this is done, the stratum of ether is drawn off and rectified, but it never equals in quality that of the former part of the operation.

It will be observed, that in this process a large additional quantity of alcohol is gradually added, and converted into ether by the original portion of sulphuric acid.

These processes may be conducted on a small scale in glass retorts, with adapters and cooled receivers; but upon the large, a leaden still or alembic is most convenient. The ether apparatus employed at the London Apothecaries' Hall, consists of a leaden still, heated by means of high-pressure steam carried through it in a convoluted leaden pipe; a tube enters the upper part of the still, for the purpose of suffering alcohol gradually to run into the acid in a way which will be presently explained. The still head is of pewter, and is connected by about six feet of tin pipe, with a very capacious condensing apparatus, duly cooled by a current of water; the receivers are of pewter, with glass lids, and have a side tube to connect them with the delivering end of the condensing pipe. In conducting this operation, too much caution cannot be observed in avoiding the proximity of fire and the use of fragile vessels; in all cases in which ether is to be dealt with, these cautions cannot be too strictly enforced, as will be evident when its properties are stated. One of the great advantages in using steam as the source of heat is, that it obviates the necessity of fire in the immediate vicinity of the apparatus.

Fig. 447.



Brande gives the following arrangement, which answers well for the preparation of ether on a large or small scale. A is the alcohol-holder; it has a grooved stopper, so that, when the stopcock is turned, the spirit may be allowed to drop with any degree of rapidity into the funnel, B, the tube which is elongated, and terminates by a small aperture near the bottom of the flask, C, which is placed in a copper-bath or sand-heat, and may be heated up to any required temperature by the gas-burner, E. F is a thermometer, properly graduated, for showing the temperature of the liquor in the flask. G is a glass tube of a sufficiently capacious bore for the conveyance of vapors from the flask to the condenser, H, which is surrounded by cold water in the vessel, I, and delivers its contents into the receiver, K. In using this apparatus, a mixture of eight parts by weight of concentrated sulphuric acid, and five parts of spirit of wine, of specific gravity 0·834, is introduced into the flask, and heated by means of the lamp till it boils, and attains a temperature of 300°. Alcohol is then suffered to drop in through the long funnel, and by adjusting its quantity on the one hand, and regulating the degree of heat on the other, by the gas-burner, the temperature of 300° is kept as steadily as possible, taking care, at the same time, that the contents of the flask are in rapid ebullition. Under these circumstances, the bulk of this liquor may be maintained uniform for several hours, and every drop of alcohol which falls in is converted into ether and water, the mixed vapors of which pass through the tube, G, into the condenser; and the receiver, K, is ultimately filled with water and ether, the latter floating upon the former.

The leading point to be attended to in this operation is the maintaining of a heat of about 300°, with rapid or even violent ebullition. The limits of the ether-producing temperature are between 260° and 310°, and the success of the operation is pretty well insured by the use of sulphuric acid and spirit of wine, in the above proportions, and of the described strength. If more alcohol, or a weaker acid be used, so as to occasion the boiling point to fall below 260°, little else than unchanged alcohol distils over; and if, by the employment of too much sulphuric acid, the boiling point rises up to, or above 320°, in that case *olefiant gas* is generated, together with variable quantities of other products.—*Brande.*

Magnus, some time since, endeavored to etherify alcohol by means of chloride of calcium at 464° Fahr., but without success. **Berthollet** has, however, succeeded in this experiment by acting on alcohol, in a close vessel, with a pure and crystalline chloride; ether was found at 572° Fahr., and at 676° ether and olefiant gas passed over, and this without the chloride undergoing any alteration.

Chloride of strontium produces the same effect, but less energetically; water, chlorides of barium and the alkaline metals, iodide and bromide of potassium, appear to possess no etherifying action, even at a temperature of 712° Fahr.

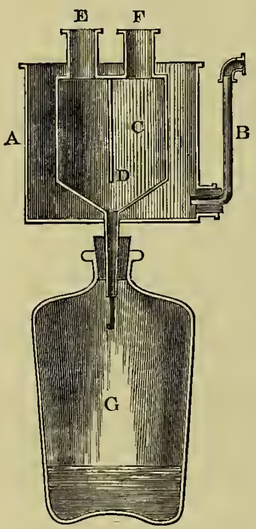
Rectification of Ether.—Dr. **Mohr** states that in rectifying commercial ether in the ordinary way, distilling it by the heat of a water-bath, with a retort and common condenser, it is impossible to effect the complete separation of the spirit, much of which passes over towards the latter part of the process. It is only by frequently ascertaining the specific gravity of the distilled product that the right time for stopping the process can be determined, and even then the ether drawn over will contain some spirit of wine, while the alcohol which remains undistilled will retain some ether. It is true that, by washing the ether with water, the whole of the alcohol may be removed from it; but this is an expensive method of effecting its purification, as the water thus used dissolves ether as well as alcohol, and thus renders another process of rectification necessary, unless it be thought less expensive to sacrifice the ether contained in the washings, than to incur the trouble of recovering it.

This chemist contrived an apparatus, by the use of which ether may be obtained in a state of purity from the unrectified liquor in one operation, while the spirit is, at the same time, left tolerably free from ether.

The principle on which the apparatus is constructed is designated by a term, which may, perhaps, appear somewhat paradoxical, namely, *warm-cooling*. The vapors arising from the impure ether are conducted through a condenser, which is kept constantly at a temperature of 118° Fahr., by the application of warm water. In this vessel, the heat being some degrees higher than the boiling point of ether, yet much lower than that of alcohol, the latter substance is condensed, while the former passes in the state of vapor into a second condenser, which is kept surrounded with cold water, and, when these can be obtained, with ice or snow.

Fig. 448 represents the *ether condenser*, which may be made of sheet-tin, or, preferably, of copper. The cylindrical vessel, A, contains the warm water. It is open at the top, and has a tube, B, inserted through a cork near the bottom, by the turning of which downwards the water may be readily drawn off. A stop-cock might be substituted for this tube, but would be more expensive. The exit pipe of the interior vessel, C, passes through the bottom of the vessel, A. It has two openings at the top to receive the glass or tin tubes, through which the vapors are conveyed to and from this apparatus. C is divided into two departments by the partition, D, so that the vapors pass down one side and up the other, and are thus more completely exposed to the influence of the warm water.

Fig. 448.



The method of conducting the process of rectification with this apparatus will be readily understood.

The crude ether, previously mixed with carbonate of potassa, so as to neutralize any free acid it may contain, is put into a retort, placed in the *steam-funnel*—Fig. 449—or in any other suitable apparatus for applying the heat of boiling water. The beak of the retort is connected by a glass or tin tube, with the opening, E, of the condenser, the delivering tube of which is fixed loosely in the mouth of a bottle, G, which is intended for the reception of the condensed spirit; and at the end of this tube there is a smaller bent tube, inserted by means of a cork, which serves to prevent the ether vapor from passing into the bottle, G, the drop of spirit which is always retained in the end of this tube keeping it closed. To the second opening, F, of the vessel C, a tube is attached, by which the ether vapor is conveyed to an efficient condenser, well supplied with cold water.

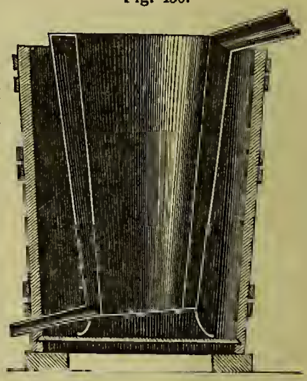
Fig. 449.

The apparatus being thus arranged, the valve of the steam-funnel is opened, so as to admit the steam to the bottom of the retort. At the same time the vessel, A, of the condenser is filled with warm water at a temperature of 118° Fahr., and this temperature is maintained by the addition from time to time of fresh water.

When the distillation commences, ether alone will at first pass over, none of which will be condensed in the first condenser; but when the process has continued for some time, spirit will begin to collect in G, while the quantity of ether passing into the next condenser will be diminished; and, lastly, the distillation of ether will entirely cease, and spirit alone will distil, being liquefied in the first condenser, and collected in G.

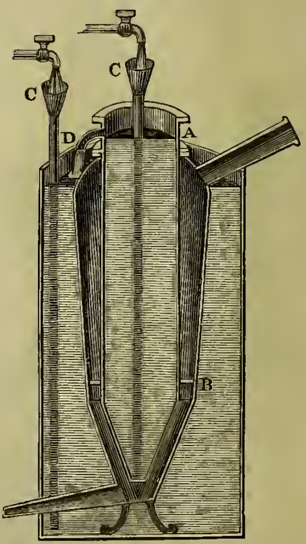
The product obtained by this process has the specific gravity of pure ether. The spirit has a faint smell of aldehyde and ether. It is readily converted into strong spirit or alcohol, by distilling it from carbonate of potassa, or from lime.

Fig. 450.



Gadda's Condensing Apparatus is depicted in Fig. 450. It consists of two conical vessels of metal of unequal size, the smaller being within the other, and the space between them closed at the top and bottom. These are placed in a tub filled with cold water, which comes in contact with the inner and outer surface of the cones, while the space between is occupied by the vapor to be condensed. Gadda's condenser is subject to the objection which applies to the common worm, that it cannot be easily and efficiently cleaned out. To obviate this objection, Mitscherlich has given to it another form, represented in Fig. 451. In this the inner part of the cone is made cylindrical, and may be taken out, so as to admit of the interior of

Fig. 451.



the apparatus being cleaned. The inner and outer pieces of the cone are united at the top by a joint, A. There is also a perforated ring, B, near the bottom, which keeps the inner cylinder in its proper place. Cold water is supplied by two jets, C, C, and the heated water is carried away by the pipes, D, D. In using this, it is necessary to have a constant supply of cold water, which can be drawn from a reservoir situated above the condenser, unless the tub containing it be large enough to hold the required quantity of water.

Fig. 452.

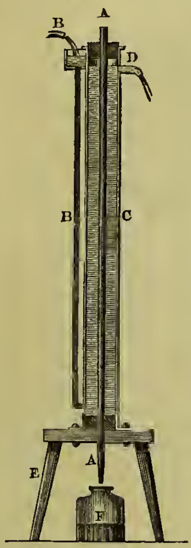
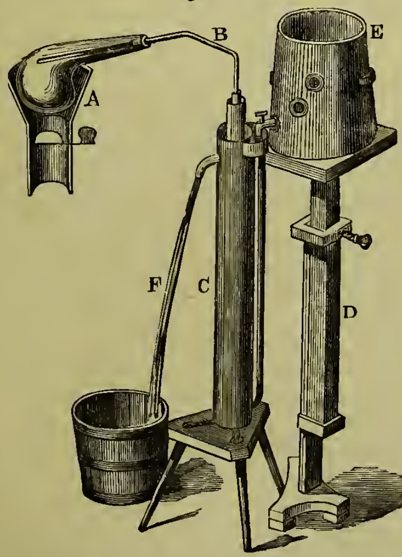


Fig. 452 is the condenser which Dr. MOHR is accustomed to employ for ether, *et cetera*. It consists of a glass tube, A, one inch in diameter, and thirty-eight inches in length, which is fitted by means of two perforated corks into the brass cylinder, C, of four inches diameter, and about thirty inches in length. A small tube, B, as shown in the drawing, conveys a stream of cold water to the bottom, and another, D, near the top, carries off the heated water. This apparatus is fixed vertically to a stool, E, under which the receiver, F, is placed.

In Fig. 453 this apparatus is represented in operation: A, the retort, placed in the funnel, with the bent tube, B, connecting it with the condenser, C. The object of this arrangement is to prevent condensation within the conducting tube, which passes some distance into the retort, and to cause none but the most volatile vapors to pass the highest angle of the tube. E is the tub for holding the supply of cold water, which runs in a continuous stream.

Fig. 453.



Composition of Ether.—When the vapor of this body is slowly conducted through a red-hot tube, it is decomposed, and resolved into water, aldehyde, and carbides of hydrogen. According to LIEBIG, three equivalents of ether $= C_{12}\ H_{15}\ O_3$, yielding—

3 Eqs. Olefiant gas,.................	$C_6\ H_6$
2 Eqs. Carbide of hydrogen,.........	$C_2\ H_4$
1 Eq. Aldehyde,.....................	$C_4\ H_4\ O_2$
1 Eq. Water,........................	$H\ O$
	$C_{12}\ H_{15}\ O_3$

Analysed by passing it over red oxide of copper, ether furnishes the following elementary constituents:—

	At weight.	Theory.	Dumas.	Editor.
4 Eqs. Carbon,....	24	64·87	65·00	64·93
5 Eqs. Hydrogen,.	5	13·51	13·80	13·75
1 Eq. Oxygen,...	8	21·62	21·20	21·32
1 Eq. Ether,.....	37	100·00	100·00	100·00

BERZELIUS for many years regarded ether as the oxide of an *organic metalloid*, or *compound inflammable basis* or *radical*, which he termed ethyl or ethul; from the Greek signifying *principle*. According to this theory, alcohol—see page 49—is a hydrated oxide of ethyl, and ether may be thus represented as an oxide of the same body:—

	At. weight.	Per cent.		At weight.	Per cent.
4 Eqs. Carbon, ..	24	64·86	= 1 Eq. Ethyl,	29	78·39
5 Eqs. Hydrogen,	5	13·53			
1 Eq. Oxygen, ..	8	21·61	= 1 Eq. Oxygen,	8	22·61
1 Eq. Ether,....	37	100·00	= 1 Eq. {Ox.of ethyl}	37	100·00

The great Swede did not live to see his theory confirmed by the isolation of ethyl; but Dr. FRANKLAND, in 1849, obtained it by acting with zinc upon its iodide at a very high temperature. Several products result, but the subjoined equation will point out to the reader how ethyl is produced:—

$$\underbrace{C_4\,H_5\,I}_{\text{Iodide of ethyl.}} + Zn = \underbrace{C_4\,H_5}_{\text{Ethyl.}} + \underbrace{Zn\,I}_{\text{Iodide of zinc.}}$$

It is a colorless, odorless, inflammable gas; burns with a brilliant white flame. Its specific gravity is 2·00394, incondensable to the liquid state at zero, but capable of being converted under pressure of 2·25 atmospheres at 37·5° into a colorless transparent fluid.

Chemists are not yet agreed as to the manner in which the elements in ether are associated, but the Editor is inclined to adopt the Berzelian view, which appears the most simple and satisfactory. Ethyl, $C_4\ H_5$, is represented by E, so that the compounds of this radical may be looked upon as quite analogous to those of potassium, ammonium, *et cetera*. Thus—

Chloride of ethyl,........................	E Cl
Chloride of ammonium,...................	Am Cl
Chloride of potassium,..................	K Cl

ETHERIFICATION.—GRAHAM remarks, that in the ordinary process of etherizing alcohol by distilling it with sulphuric acid, two distinct chemical changes are usually recognised; namely, first, the formation of sulphovinic acid—bisulphate of oxide of ethyl; and, secondly, the decomposition of the compound named, and liberation of ether. The last step or actual separation of the ether is referred to its evaporation, in the circumstances of the experiment, into an atmosphere of steam and alcohol vapor, assisted by the substitution of water as a base to the sulphuric acid in the place of the ether. The fact that ether is not brought off by a current of air passing through the heated mixture of sulphuric acid and alcohol, is subversive of the last explanation, as it demonstrates that the physical agency of evaporation is insufficient to separate ether. Induced to try whether ether could not be formed without distillation, GRAHAM obtained results which appear to modify considerably the views that might otherwise be taken of the nature of the etherizing process. From six experiments which he performed with this view, he arrived at the conclusion that the most direct or normal process for preparing ether appears to be, to expose a mixture of oil of vitriol with from four to eight times its volume of alcohol of eighty-three per cent. to a temperature of 370° for a short time. Owing to the volatility of the alcohol, this must be done under pressure, as in a sealed glass tube. The sulphuric acid then appears to exert an action upon the alcohol, to be compared with that which the same acid exhibits when mixed in small proportion with the essential oils. Oil of turpentine, mixed with one-twentieth its volume of sulphuric acid, undergoes an entire change, being chiefly converted into a mixture of two hydrocarbons, tereben and colophen, one of which has a much higher boiling point and greater vapor density than the oils of turpentine. This carbide of hydrogen does not combine with the acid, but is merely increased in atomic weight and gaseous density without any further derangement of composition, by a remarkable polymerizing action—as it may be termed—of the sulphuric acid. So of the hydrocarbon of alcohol; its density is doubled in ether by the same polymerizing action. Chloride of zinc effects, with alcohol at an elevated temperature, a polymeric catalysis of the latter, of the same character, but in which hydrocarbons are formed of even greater density, and free from oxygen. This view of etherification is only to be considered as an expression of the theory of that process which has long been so ably advocated by MITSCHERLICH, who considers the formation of ether as a case of *decomposition by contact*, conceiving that, at a certain temperature—regulated by the dilution of the acid—alcohol, on merely coming into contact with sulphuric acid, is resolved into ether and water. He cites, as parallel cases, the decomposition of oxidised water by gold, silver, and binoxide of manganese, and the action of spongy platinum in determining the combination of certain gases, together with the conversion of sugar into alcohol and carbonic acid by the *contact* of ferment, and of starch into sugar, by means of sulphuric acid.

The formation of sulphovinic acid appears not to be a necessary step in the production of ether; for it has been found that the etherizing proceeded most advantageously with bisulphate of soda, or with sulphuric acid mixed with a large proportion of alcohol and water, which would greatly impede the production of sulphovinic acid. It appears, indeed, that the combination of alcohol with sulphuric acid, in the form of sulphovinic acid, greatly diminishes the tendency of the former to be afterwards etherized; for, when the proportion of oil of vitriol was increased, which would give much sulphovinic acid, the formation of ether rapidly decreased. The previous conversion of alcohol into sulphovinic acid appears, therefore, to be actually prejudicial, and to operate as an obstacle to its subsequent transformation into ether.

The operation of etherizing has attained a kind of technical perfection in the beautiful continuous process now followed. The first mixture of alcohol and sulphuric acid is converted into sulphovinic acid—the sulphate of ether and water—which acid salt appears to be the agent that polymerizes all the alcohol. Bisulphate of soda, with a slight excess of acid, acts upon alcohol in the same manner, and its substitution of the acid sulphate of ether would have a certain interest, in a theoretical point of view, although a change of no practical importance in the preparation of ether.—*Journal of the Chemical Society.*

PROPERTIES OF ETHER.—Ether is a highly volatile, transparent, colorless, limpid liquid, of a peculiar penetrating and agreeable odor, and a pungent and sweetish taste. It is neither acid nor alkaline; has a high refractive power in regard to light; is a non-conductor of electricity; and is sparingly soluble in water, nine volumes of the latter dissolving one of ether. It is dissolved by alcohol in all proportions. It abstracts bichloride of mercury, terchloride of gold, bichloride of platinum, and the sesquichloride of iron from their aqueous solutions. Bromine and iodine are readily soluble in ether; but the solutions, by keeping, undergo decomposition. Sulphur and phosphorus are sparingly dissolved by it. The ethereal solution of the former is luminous in the dark when poured on hot water. It dissolves the volatile oils, most of the fatty and resinous substances, some of the vegetal alkalies, urea, osmazom, gun-cotton—forming collodion—and caoutchouc.

Ether boils at 96° or 97° Fahr., and produces, by its evaporation, a great degree of cold. At the temperature 62·4°, the vapor of ether balances a column of mercury fifteen inches high, or half the weight of the atmosphere. When cooled to minus 24°, it begins to crystallize in brilliant white plates; and at minus 47°, it becomes a white crystalline solid. When its vapor is made to traverse a red-hot porcelain tube, it deposits within it one-half per cent. of charcoal, and there is condensed in the receiver one and two-thirds per cent. of a brown oil, partly in crystalline scales, and partly viscid. The former portion is soluble in alcohol, but the latter only in ether. The remainder of the decomposed ether consists of bicarbide of hydrogen, tetrahydric carbide, carbonic oxide gas, and one per cent. at most of carbonic acid.—*Ure.*

Ether takes fire readily, even at some distance from a flame, and it should not, therefore, be poured from one vessel to another in the neighborhood of a lighted candle. It may be likewise set on fire by the electric spark. It burns entirely away with a bright fuliginous flame. When the vapor of ether is mixed with ten times its volume of oxygen, it ignites with a violent explosion, absorbs six times its bulk of oxygen, and produces four times its volume of carbonic acid gas.

PLANCHE states that ether exposed to air or light, as in bottles which are frequently used, becomes less perfectly volatile, and less capable of dissolving fixed oil, in consequence of the formation of a little acetic acid. The presence of this acid is not at first apparent, because it forms acetic ether, but it gives the ether a peculiar odor, and in time it becomes acid to tests. The best way of preserving ether is to keep it in small well-stopped bottles, or even in sealed tubes, and in a dark place. In some very old ether, which had been often opened, and the boiling point of which was elevated to 130°, **GAY-LUSSAC** found an oily matter, crystallizable, and possessing an ethereal odor.

According to **DÖBEREINER**, ether which has been exposed to the atmosphere contains free nitrogen, the oxygen of the air having combined with the spirit.

MALAGUTI affirms, that when a little ether is introduced into chlorine, the gas is absorbed, and peculiar compounds result. When bubbles of chlorine are passed into ether, they often cause inflammation; and if a small quantity of ether be effused into a large jar of gaseous chlorine, previously warmed, it occasionally happens that a considerable explosion ensues. If the ether be cooled, and chlorine transmitted through it, hydrochloric acid is formed, together with a fluid containing chlorine, which, when saturated with potassa, produces chloride of potassium and acetate of potassa.

SCHÖNBEIN found that a little pure ether put into a bottle filled with oxygen or atmospheric air, and exposed to diffused light, the bottle being occasionally shaken, had partially changed its nature after the lapse of four months. Although producing no action upon blue litmus paper, it discharged the color of a solution of indigo, converted phosphorus when immersed in it into phosphorous acid, eliminated iodine from iodide of potassium, changed protosulphate of iron to basic and sesquisulphates, transformed ferrocyanide into the ferricyanide of potassium, sulphate of lead into sulphite, *et cetera.*

PEREIRA says that the operation of ether upon the system is analogous to that of alcohol, but much more rapid and transient. *Swallowed in moderate doses,* it produces a powerful impression on the mouth, throat, and stomach; allays spasm, and relieves flatulence; but, according to some observers, it augments neither the heat of the body nor the frequency of the pulse. Its first effects on the cerebral functions are those of an excitant, but the subsequent ones are of a depressing nature. *In somewhat larger doses,* it produces intoxication like that caused by alcohol. *In excessive doses,* it occasions nausea, a copious flow of saliva, giddiness, and stupefaction.

The long and habitual use of ether diminishes the effect of this substance over the system, and, therefore, the dose must be proportionally increased. Dr. **CHRISTISON** mentions the case of an old gentleman who consumed sixteen ounces every eight or ten days, and had been in the habit of doing so for many years. Yet, with the exception of an asthma, for which he took the ether, he enjoyed tolerable health. **BUCQUET**, who died of scirrhus of the colon, with inflammation of the stomach and of the intestines generally, imbibed, before his death, a pint of ether daily, to alleviate his excruciating pains.

When the vapor of ether, sufficiently diluted with atmospheric air, is *inhaled,* it causes irritation about the epiglottis, a sensation of fulness in the head, and effects analogous to those caused by the protoxide of nitrogen—laughing gas—moreover, persons peculiarly susceptible of the action of the one, are also powerfully affected by the other. If the air be too strongly impregnated with ether, stupefaction ensues. In one case this state continued, with occasional periods of intermission, for more than thirty hours; for many days the pulse was so much lowered, that considerable fears were entertained for the safety of the patient. In another case, an apoplectic condition, which continued for some hours, was produced. The anæsthetic properties of this vapor are well known. They are similar to those of chloroform, which has almost entirely superseded it. In surgical operations it has been much used for the purpose of destroying sensibility; but preference is now given to chloroform.

The effects of ether on animals have been determined by **ORFILA**, who found that half an ounce, introduced into the stomach of a dog, with the œsophagus tied, caused attempts to vomit, diminished muscular power, produced insensibility, and, in three hours, death. Three drachms and a half injected into the cellular tissue of the thigh, caused death on the fourth day. **JAGER** found that half an ounce of ether acted as a fatal poison to a crane; at the end of forty-eight hours its odor could be readily detected in the body. He made similar experiments on pigeons and ducks. One of the last-mentioned animals took altogether an ounce of ether, yet was not dead at the end of twenty-four hours.—*Pereira.*

GORUP-BESANEZ has published some experiments upon the composition of the blood before and after the inhalation of ether. He invariably found an increase of water, and diminution of blood corpuscles.

Uses.—In medicine, ether is principally valuable as a speedy and powerful agent in spasmodic and painful affections, not dependent on local vascular excitement, and which are accompanied by a pale, cold skin, and a small, feeble pulse. If administered during a paroxysm of spasmodic asthma, it generally gives relief, but has no tendency to prevent the recurrence of attacks. In cramp of the stomach, flatulent colic, *et cetera,* its happy effects are well established. In the latter stages of continued fever, ether is sometimes admissible. **DESBOIS DE ROCHEFORT** administered it successfully in intermittent fevers. Headache, of the kind popularly called nervous, that is, unconnected with vascular excitement, is speedily relieved by ether. In flatulence of the stomach, it may be taken in combinanation with some aromatic water. As an antidote against sea-sickness, it should be swallowed in a glass of white wine. **DURANDE** recommends a mixture of three parts of ether and two of oil of turpentine as a solvent for biliary calculi. **BOURDIER** employed ether, in infusion of male fern, to expel tape-worm. In faintness and lowness of spirits it is a popular remedy. It has been employed in cases of poisoning by mushrooms and hemlock. The principal external use of ether is to produce cold by its speedy evaporation. Dropped on the forehead, or applied by means of a piece of thin muslin, ether diminishes vascular excitement by the degree of cold occasioned by its rapid volatilization, and is exceedingly efficacious in headache and inflammatory conditions of the brain. In burns and scalds it may be employed as a refrigerant. If its evaporation be stopped or checked, as by covering it with a compress, it acts as a local irritant, causing rubefaction; and if the application is long continued, vesication ensues. It is used with friction as a local stimulant.—*Pereira.*

Ether finds but very limited application in the analysis of inorganic bodies. It serves, in fact, almost exclusively to detect and isolate bromine, and for this purpose the officinal ether of commerce is sufficiently pure and strong. It is used in the preparation of a great many organic bases; the circumstance of its being so volatile is a great recommendation to its employment.

Adulteration.—The ether of commerce is generally unsophisticated, but it is, nevertheless, found much less pure or strong than it should be. The chief adulteration to which ether is liable is by an admixture of alcohol, in which it is soluble in all proportions. The presence of spirit of wine in ether, however, is very easily recognised by pouring a certain quantity of the suspected liquid into a graduated tube, and adding a small quantity of water, which, dissolving the alcohol, produces a much more considerable diminution of volume if the ether contain that body, than when it is pure; of course the mixture should be shaken. It should be recollected that ten parts of water dissolve one of ether, and, consequently, that a diminution in that proportion will always take place, even with pure ether, for which an allowance must be made.—*Normandy.*

Sometimes ether also contains water, which is the case with what is termed *washed ether;* and if ether has been long prepared, it is often slightly acid, and leaves a peculiar odor when rubbed upon the hand. In order to procure from it perfectly *pure ether*, it must be well shaken in a close vessel with about twice its bulk of water, and allowed to separate upon the surface of the mixture; it is then poured off, and a sufficient quantity of well-burned lime added to it, whereby the water which it had acquired by the agitation is abstracted; the mixed ether and lime are then distilled, care being taken to prevent all escape of vapor, and to keep the condensing receivers cold; the first that distils over may be regarded as *pure ether*, free from alcohol and water.—*Brande.*

Having treated at some length of ether, properly so called, it will now be desirable to append the preparation, composition, and properties of a few other substances, partaking of analogous properties, which are daily used, or will sooner or later come into request, for the purposes of the rectifier, perfumer, confectioner, *et cetera.*

ACETIC ETHER.—The preparation, *et cetera*, of this compound has been fully given at page 41. It may be stated here, that, according to PELOUZE, when carbonic acid is passed through an alcoholic solution of acetate of potassa, acetic ether and bicarbonate of potassa are formed.

The annexed equation represents the decomposition:—

$$\underbrace{HO,\ C_4\ H_5\ O}_{\text{Alcohol.}} + \underbrace{KO,\ C_4\ H_3\ O_3}_{\text{Acetate of potassa.}} + \underbrace{2\ CO_2}_{\text{Carbonic acid.}}$$

$$= \underbrace{C_4\ H_5\ O,\ C_4\ H_3\ O_3}_{\text{Acetic ether.}} + \underbrace{HO,\ CO_2 + KO,\ CO_2}_{\text{Bicarbonate of potassa.}}$$

This is a curious instance of etherification at common temperatures; the insolubility of the bicarbonate in alcohol is probably concerned in the action.

BUTYRIC ETHER—BUTYRATE OF OXIDE OF ETHYL.—This compound is instantly formed when two parts of butyric acid, two parts of alcohol, and one of sulphuric acid are mixed; it rises to the surface, and is to be washed and rectified over chloride of calcium. It is also very readily obtained by saponifying butter with a concentrated solution of potassa, and dissolving the soap in the smallest requisite quantity of strong alcohol with the assistance of heat, adding a mixture of alcohol and sulphuric acid to this solution until it has a strong acid reaction, and then submitting it to distillation as long as the product has a fruity odor.

The pure ether may be separated from this product by repeated rectification and treatment with chloride of calcium. According to BORNTRAGER, it appears, when prepared in this manner, to consist solely of the ether of butyric acid. This compound, which possesses in so remarkable a degree the pleasant odor of apples, is at present very much used as an aroma in the manufacture of rum.

CAPRIC ETHER—CAPRATE OF THE OXIDE OF ETHYL.—This is formed by passing dry hydrochloric acid gas into a solution of capric acid in alcohol until saturation takes place. Upon the addition of water, the capric ether separates and floats as an oily layer upon the menstruum. It should be well aspersed with water, then dried and digested with fused chloride of calcium. It eliminates in a high degree a pine-apple odor.

CAPROIC ETHER is made precisely in the same way as the above, substituting caproic for capric acid. Caproate of oxide of ethyl is also exceedingly fragrant like pine-apple.

ENANTHIC ETHER.—The presence of a peculiar compound, upon which the fragrancy and persistent odor of certain wines depends, has already been adverted to at page 105. It is obtained by agitating the oil derived from brandy or from grain spirit—*weinfuselöl*—which is a mixture of enanthic acid and enanthic ether, with a solution of carbonate of soda, till the free acid is neutralized; heat is then applied, and the enanthic ether separates upon the surface, and may be dehydrated by chloride of calcium. It is an oily liquid, of a strong, and even intoxicating vinous odor, soluble in ether and in alcohol, but not in water. It is not decomposed by carbonate of potassa. The specific gravity of enanthic ether is 0·862, and the density of its vapor = 10·5.—*Brande.*

HYDROCHLORIC ETHER—CHLORIDE OF ETHYL.—*Sweet or dulcified spirit of salt* was a favorite preparation with the old chemists. They conceived it to possess some peculiar solvent powers in regard to the salts of gold. It was also used in medicine. It was prepared in various ways; either by distilling a mixture of alcohol and hydrochloric acid, or of chloride of sodium, sulphuric acid, and alcohol.

Chloride of Ethyl, remarks Brande, may be obtained by subjecting to careful distillation a concentrated solution of hydrochloric acid gas in alcohol; or a mixture of one part of alcohol, one of sulphuric acid, and two of fused and finely-powdered chloride of sodium; or a mixture of alcohol with chloride of antimony, or chloride of tin. In all these cases, chloride of ethyl passes over; it should first be transmitted into warm water, by which its adhering acid and alcohol are abstracted, and its vapor may then be condensed by conducting it through a cold tube, and receiving it in a bottle surrounded by ice and salt. Boullay's process for its preparation, as given in Brande's *Manual of Chemistry*, is as follows:—Absolute alcohol is saturated with dry hydrochloric acid gas, and the resulting liquor introduced into a flask connected with two Woulfe's bottles, the first of which contains water at about 80°, while the second is immersed in a mixture of ice and salt. On applying heat to the flask, the vapor of alcohol and hydrochloric acid are retained in the first bottle whilst the vapor of the ether passes over, and is condensed in the second.

According to Brande, chloride of ethyl is a limpid, colorless liquid, of a peculiar penetrating odor, and a sweetish acrid flavor. It is neutral. Its specific gravity is 0·874 at 420°. It boils at 60°. The density of its vapor is 2·219. When cooled down to 10°, it crystallizes in cubes. It is soluble in about fifty parts of water, but in all proportions in alcohol and ether proper. It dissolves sulphur and phosphorus, and the fat and volatile oils. Its components are—

	At. weight.	Theory.	Dumas.
4 Eqs. Carbon,	24	36·9	37·73
5 Eqs. Hydrogen,	5	7.7	7·70
1 Eq. Chlorine,	36	55.4	54·57
1 Eq. Chloride of ethyl,	65	100·0	100·00

or,

	At. weight.	Dumas.
1 Eq. Ethyl,	29	35·43
1 Eq. Chlorine,	36	54·57
1 Eq. Chloride of ethyl,	65	100·00

Chloride of ethyl is a highly diffusible stimulant like the other ethers, but is rarely employed alone, though it has been used as an antispasmodic. It is usually prepared by dissolving hydrochloric ether in an equal volume of rectified spirit. The action of this compound seems to be similar to that of nitric ether. A scruple of it thrown into the veins of a buck augmented the renal secretion. An ounce and a half injected into the jugular vein of a dog coagulated the blood, caused difficulty of breathing, and death. It has been used in dyspeptic affections connected with hepatic obstructions. In hectic fever, Berends found its continued use beneficial.—*Pereira.*

Nitric Ether—Nitrate of Oxide of Ethyl.—The mutual action of nitric acid and alcohol had been always found to be so violent that the production of this ether was believed impossible, until Millon remarked that the intense action is due to the nitrous acid which ordinary nitric acid always contains, and that by using absolutely pure nitric acid, and preventing the formation of nitrous acid, the real nitrate of ether can be obtained with facility. To prevent the production of nitrous acid, he employs urea, which is immediately decomposed by and destroys nitrous acid. When two ounces of absolute alcohol and one ounce of strong nitric acid are mixed, and twenty grains of urea are added, the reaction is very moderate; and after some time a very heavy oily liquid begins to separate, and is increased in quantity by the addition of water. This is true *nitric ether.* It is colorless, has a specific gravity of 1·112, and boils at 184°. Its odor and taste are agreeable, and the alkalies decompose it into alcohol and nitric acid.—*Kane.*

Millon gives the following as its composition:—

	At weight.	Theory.	Millon.
4 Eqs. Carbon,	24	26·4	26·50
5 Eqs. Hydrogen,	5	5·5	5·72
6 Eqs. Oxygen,	48	52·7	52·52
1 Eq. Nitrogen,	14	15·4	15·26
1 Eq. Nitric ether,	91	100.0	100·00

=

1 Eq. Ether,	37	40·8
1 Eq. Nitric acid,	54	59·0
1 Eq. Nitric ether,	91	100·0

This ether, dissolved in alcohol or distilled with it, is largely used in medicine.

Spirit of nitric ether, as the solution or distillate is termed, is a colorless, limpid liquor, having a fragrant ethereal odor, somewhat analogous to that of ripe apples, and a pungent aromatic taste. It is very volatile, producing much cold by its evaporation. It is very inflammable, and burns with a whitish flame. It is principally distinguished by its peculiar odor, its inflammability, its lightness, and its miscibility with water. The spirit of nitric ether of the shops usually strikes a deep olive color with the protosulphate of iron, thereby indicating the presence of binoxide or an acid of nitrogen; and produces, with tincture of guaiacum, a blue tint, which passes through various shades of green: this last effect depends on the presence of an acid of nitrogen. These effects are not invariably produced; for in some spirit of nitric ether which Pereira had for several years they did not take place. According to this pharmacologist, it is employed as a diuretic in some disorders of children, and in mild dropsical complaints, as in the anasarca which follows scarlatina. It is given in conjunction with squills, acetate or nitrate of potassa, or foxglove. As a refrigerant and diaphoretic, it is used in febrile complaints, in combination with the acetate of ammonia and emetic tartar—tartrate of antimony and potassa. As a carminative, it is frequently useful in relieving flatulence and allaying nausea. From its volatility, it may be applied to produce cold by its evaporation. Spirit-dealers employ it as a flavoring ingredient.

Nitrous Ether—Nitrite of the Oxide of Ethyl.—The process ordinarily used for preparing nitrous ether is that of Thenard; and consists in treating alcohol directly with nitric acid of commerce. For this operation, the ordinary distillatory apparatus is employed, the receiver of which is surrounded by a refrigerant mixture, and the tubulure is furnished with a safety tube communicating with three Woulfe's receivers, half filled with a saturated solution of chloride of sodium, and surrounded by a refrigerant mixture.

The capacity of the still should be equal at least to five times the bulk of the mixture of alcohol and nitric acid employed; and, notwithstanding all the care which may be observed in heating the still, the mass intumesces so much at a certain period, that the fire is always obliged to be suddenly withdrawn, and, for the greatest part of the time, wet cloths have to be placed on the still head, so violent is the reaction. These various manœuvres are far from being without risk, as the retort may sometimes blow up.

The danger in which the operator is placed is doubtless a very serious inconvenience; but it is not the only one; indeed, by proceeding thus, only about one-fifth of the alcohol employed is converted into nitrous ether; since there is produced, at the same time as the nitrous ether, water, acetic, formic, and carbonic acids, and aldehyde; there are also formed binoxide and protoxide of nitrogen, and nitrogen itself may be found in the free state, so energetic is the decomposition. Finally, a small quantity of undecomposed nitric acid passes into the receiver.

Throughout this molecular movement, a certain amount of nitric acid is reduced to the state of nitrous acid, which, combining in the nascent state with ether, gives nitrous ether, but in very small quantity in proportion to the alcohol employed.

Grosourdi considers that electricity performs the principal part in this reaction, at the moment when the various molecules enter into new combinations, neutralize their contrary electricities, and develop throughout an enormous amount of caloric which, by its presence, causes all the danger of the experiment.

From these considerations, he thought it necessary to seek for a process, which, by avoiding the too violent action of nitric acid or alcohol, should not only render the operation free from danger, but also convert into nitric ether, if not the whole of the alcohol employed, at least the greater part of it.

With this view, nitric acid was made to act in the nascent state on alcohol, or rather on the ether, also in the nascent state; but this process not succeeding to his entire satisfaction, he put nitrous acid in the nascent state in contact with ether, also in the same state, since the alcohol employed had been previously treated with concentrated sulphuric acid; by this means the object proposed was attained.

Nitrite of potassa is prepared by deflagrating in a Hessian crucible one hundred parts of commercial nitrate of potassa, previously reduced to very fine powder and intimately mixed with 12·07 parts of lamp-black, which may be regarded as almost pure carbon. When the deflagration is concluded, the crucible is covered, removed from the fire and allowed to cool; after cooling, it contains a very white and very hard mass; this is nitrite of potassa with traces of carbonate and subsilicate of the same base. These two salts will be in so much the smaller proportion as the mass has been less powerfully heated, and especially as the deflagration has been more rapid.

The following equation will explain the reaction; the carbonate and the subsilicate of potassa being omitted, as their presence is only accidental:—

$$\underbrace{2\,C}_{\text{Carbon.}} + \underbrace{KO, NO_5}_{\text{Nitrate of potassa.}} = \underbrace{KO, NO_3}_{\text{Nitrite of potassa.}} + \underbrace{2\,CO}_{\text{Carbonic oxide.}}$$

Before entering into the details of this new process, Grosourdi states the following facts:—

Nitrite of potassa, pulverized and put into a test tube, with a sufficient quantity of alcohol, at 88·06 of alcoholometer, to form over it a layer of a few lines in thickness, no longer disengages nitrous acid, which is so easily recognised by its odor and color when treated with sulphuric acid—a reaction which always takes place when this salt is treated with sulphuric acid, either with or without water, and which is a characteristic reaction of this kind of salt. It would be necessary, therefore, before employing the sulphuric acid, to expel the alcohol.

The reaction of the nitrites, treated with sulphuric acid when protosulphate of iron is present, is also modified by the liquids containing a certain quantity of alcohol. Indeed, the brown coloration appears but slowly, and forms an areola round the crystals of the salt of iron, but it disappears immediately on agitating the menstruum.

To prepare nitrous ether, he put into a glass retort 17·50 parts of alcohol of 85°, twenty-five of nitrite of potassa, and twelve of sulphuric acid, and by this means converted into nitrous ether almost all the real alcohol employed, as is proved by the annexed equation:—

$$\underbrace{KO, NO_3}_{\text{Nitrite of potassa.}} + \underbrace{HO, SO_3}_{\text{Sulphuric acid.}} + \underbrace{HO, C_4\,H_5\,O}_{\text{Alcohol.}} = \underbrace{C_4\,H_5\,O, NO_3}_{\text{Nitrous ether.}} + \underbrace{KO, SO_3}_{\text{Sulphate of potassa.}} + \underbrace{2\,HO}_{\text{Water.}}$$

The apparatus is composed of a tubulated retort, the tubulure of which is closed with an accurately-fitted stopper; it is made to communicate with a tubulated receiver by means of two adapters, arranged end to end; to the tubulure is fixed, instead of the ordinary straight tube, one with two bends; the longer of these, at least twenty-three and a half inches in length, dips into a deep glass filled with mercury. This is simply the ordinary distillatory apparatus, slightly modified.

Care must be taken that all the corks which unite the different pieces be not only hermetically sealed, but also that they be tied round with string, and then covered with a layer of luting. The retort is placed in an empty water-bath, into which the water is only introduced when necessary to raise the temperature; and the receiver is put into a vessel containing cold water, which is continually renewed, so as to keep it almost entirely covered; if it can be surrounded with ice or even with a refrigerant mixture, so much the better; but this is not indispensable, for very cold water has always answered the purpose. The apparatus thus arranged is suitably maintained and fixed by means of supports.

The object of the tube dipping in mercury is twofold; first, to prevent the loss of a certain quantity of ether, which, without this precaution, would make its way into the atmosphere; secondly, to produce pressure, and especially to facilitate condensation.

This done, nitrite of potassa in fine powder is introduced into the retort; then half the alcohol employed is added, and the whole well mixed. The sulphuric acid previously mixed with the other half of the alcohol is now poured through a funnel by small portions at a time, taking care to agitate frequently; when this mixture has become quite cold, only a few bubbles of carbonic acid are disengaged, and no nitrous acid. The liquid remains perfectly colorless, and there is no apparent reaction, nor even any appreciable elevation of temperature.

The retort is then closed, and the whole is left to itself at the ordinary temperature, which should not exceed 50°. When the experiment has been made, and several times repeated, care must be taken to agitate the mixture every seven or eight hours, in order to change the points of contact, and especially to facilitate the reaction.

At the end of eight hours' contact, when the retort is opened for the first time, the peculiar odor of the nitrous ether is already slightly appreciable; but in twenty-four hours, when it is again opened for the purpose of stirring the mixture, a powerful odor of apples is perceived.

After forty-eight hours' contact, pour into the bath water at the temperature of 86°, and maintain it at this point; then the nitrous ether soon distils over, and passes into the receiver.

The operation should be conducted very slowly, without raising the temperature of the water-bath beyond 95°. When there is no more liquid in the retort, and the mass appears semi-solid, remove, by means of a siphon, all the liquid condensed in the receiver; then pour into the retort sufficient water at 113° to cover the saline mass.

This done, mix the whole well by means of the agitator; then continue the distillation, raising the temperature of the sand-bath to 113° and 122°; and by operating thus, there is obtained in the receiver a further quantity of nitrous ether, but which is not quite so pure as the first portions. The liquid remaining in the receivers, and which by cooling deposits crystals of sulphate of potassa, is yellow, and has a very powerful nitrous odor, partaking also of that of slightly rancid fatty matters. Its color and smell are due in a great measure to the presence of a peculiar substance which will be presently noticed.

From what has just been stated, it is evident that by this process the operator is exposed to no danger, since he is always able to govern the operation, which must be conducted slowly if he wishes to obtain a good product. As to the greater production of nitrous ether, this may easily be ascertained by weighing, after rectification, the ether resulting, and it will be found that it weighs more than two-thirds of the alcohol employed.

Thus obtained, the nitrous ether which has been removed from the receiver by means of a siphon, scarcely reddens litmus paper, and, most frequently, requires only a simple distillation at 68°, or 71° at most, if the operation has been properly conducted, to be pure.

When purified, this nitrous ether is perfectly colorless, and gives out a sweet odor of apples; it does not redden litmus paper the moment it is dipped in it, but when once this paper is impregnated, it soon becomes red by exposure to the air—at first gradually, and afterwards more rapidly, and ultimately the same as with the powerful acids. This reaction is the result of the decomposition of nitrous ether under the influence of the oxygen of the air, which, doubtless, makes the nitrous ether pass unto the state of nitric acid, by setting the ether at liberty. This body should consequently be kept in well-stopped flasks, so as to avoid all contact with the atmosphere.

As to the ethereal liquid obtained after having added water to the retort, it is powerfully acid, and often of a yellowish color, especially if the temperature has been raised too high. For its purification, it must be treated in a stoppered flask with one-tenth of its weight of pure carbonate of potassa, in very fine powder, taking care to agitate the flask very frequently, so as to multiply the points of contact, and each time to allow the carbonic acid disengaged during the agitation to escape. After half an hour's contact, or more, if the liquid is still acid to litmus paper, it is distilled as directed above, which should be repeated several times, if necessary; thus a further quantity of perfectly pure nitrous ether is obtained.

In all these cases, the flask should never be filled beyond two-thirds of its capacity.

This ether is perfectly colorless, although some chemists assign to it a yellow tinge; but when in this state, it is not pure, holding in solution a peculiar substance, which, when isolated, is a reddish, yellow oleaginous body, having a peculiar smell resembling that of fatty matters left for a certain time to the action of damp air. It is an odor like that of rancid matter mixed with something aromatic; and is so persistent, that when the fingers touch it, they remain for a long time impregnated. It is very soluble in the ethers and in alcohol.

GROSOURDI procured this substance by treating with ether the residue resulting from the spontaneous evaporation in the sun, under a bell glass containing quicklime, of the yellowish liquid which contained the crystals of sulphate of potassa, after the preparation of the nitrous ether; or else by heating in the same manner the residue of the purification of this same ether, when it was obtained colored, owing to too great heat in its preparation. Then the ethereal liquid resulting from it, left to spontaneous evaporation, as has been already stated with regard to the yellow liquid from which the sulphate of potassa is deposited, left this body in the pure state at the bottom of the capsule, the ether being entirely disengaged.

GROSOURDI'S process for the fabrication of nitrous ether is certainly to be preferred to that of THENARD, inasmuch as it is free from danger, and furnishes a larger quantity of purer ether. When nitrite of potassa cannot be obtained, the following menstruum may be used:—

Nitrate of potassa,	57·48 parts.
Commercial sulphuric acid at 60°,	25·89 "
Alcohol at 86°, of the alcoholometer	116°.

The following represents the change:—

$$\underbrace{2\,(HO,\,C_4\,H_5\,O)}_{\text{Alcohol.}} + \underbrace{KO,\,NO_5}_{\text{Nitrate of potassa.}} + \underbrace{HO,\,SO_3}_{\text{Sulphuric acid.}} =$$

$$\underbrace{C_4\,H_5\,O,\,NO_3}_{\text{Nitrous ether.}} + \underbrace{KO,\,SO_8}_{\text{Sulphate of potassa.}} + \underbrace{5\,HO}_{\text{Water.}} +$$

$$\underbrace{C_3\,H_3}_{\substack{\text{Carbide of}\\ \text{hydroden.}}} + \underbrace{CO}_{\substack{\text{Carbonic}\\ \text{oxide.}}}$$

From this it may be readily seen, that the reaction is much more complicated than in the former process; indeed, an equivalent of alcohol is lost to the etherization, since, in being converted into nitrous acid, under the influence of the nitric acid, it is reduced into water, carbonic acid, and the carbide of hydrogen, which constitutes the oleaginous substance mentioned.

After having mixed together, with the proper precautions as to the elevation of temperature, the alcohol and sulphuric acid, the mixture is poured, after complete cooling, into the tubulated retort, the apparatus having been previously arranged as above stated. This done, the nitrate of potassa in fine powder is introduced in small quantities at a time; care is taken, at the same time, to agitate the mixture well with the whalebone agitator, in order to multiply the points of contact; the still is then closed, and the whole is left to itself for three days at a temperature of 59°; the mixture is then carefully agitated every seven or eight hours.

At the moment when the nitrate of potassa is put into the mixture of alcohol and sulphuric acid, there is neither elevation of temperature nor any apparent reaction; but when the mixture is agitated for the first time, at the end of seven or eight hours' contact, a slight odor of nitrous ether is perceived, which becomes more and more powerful, so that at the end of forty-eight hours it is very perceptible when the retort is opened. At this moment, by the agitation occasioned in the mixture by this operation, a multitude of small bubbles of carbonic acid are disengaged, so that the mass appears to be effervescent; this phenomenon is also apparent at the end of twenty-four hours' contact, but in a much less degree. Then the liquor containing the saline mass is colored yellow.

At the end of from sixty to seventy-two hours, water at the temperature of 77° to 80° is put into the bath, which is maintained at this point, and nitrous ether is soon observed to distil over into the receiver in which some has already condensed. The operation should be very slowly conducted to obtain a good product. Towards the termination of the experiment—when the greater part of the liquid contained in the retort has passed into the receiver—the temperature of the bath may be raised to 122°, but the liquid condensed in the receiver must be removed.

The operation being completed—that is to say, when no more nitrous ether comes over—one proceeds to purification and rectification, as already pointed out in speaking of the same operation for nitrous ether obtained by means of nitrite of potassa.

During the whole time that these processes are being performed, the bulk of the mixture is not sensibly augmented; consequently, the operator is not exposed to any danger, and has the greatest facility in conducting the operation, which, for the chief part of the time, does not even require his presence.

Any of the nitrates may be employed, but preference is given to that of potassa, as being the most economical and most abundant in commerce. As to the nitrites, they may all be submitted to that of potassa, but those in which the base and acid have only a feeble affinity for each other would ill fulfil the object.—*Journal de Chimie Médicale.*

PELARGONIC ETHER is procured in a similar manner to the other fatty compounds; that is, by passing hydrochloric acid gas through a solution of pelargonic acid in alcohol. It is an oily liquid, possessing a very peculiar odor, and boiling at 240°. According to FRANKLAND, it is to this that whisky owes its flavor; and GREGORY states that it is now manufactured by a secret process, and vended at a high price, for the purpose of imparting to new whisky the fragrance of old. The occurrence of pelargonic acid in whisky shows that the acid is derived from sugar.

The Editor appends the formulæ representing the different ethers described:—

Name.	Formula.
Acetic ether,	$C_4\,H_5\,O,\,C_4\,H_3\,O_3$.
Butyric ether,	$C_4\,H_5\,O,\,C_8\,H_7\,O_3$.
Capric ether,	$C_4\,H_5\,O,\,C_{20}\,H_{19}\,O_3$.
Caproic ether,	$C_4\,H_5\,O,\,C_{12}\,H_{11}\,O_3$.
Enanthic ether,	$C_4\,H_5\,O,\,C_{14}\,H_{13}\,O_2$.
Hydrochloric ether,	$C_4\,H_5\,Cl$.
Nitric ether,	$C_4\,H_5\,O,\,N\,O_5$.
Nitrous ether,	$C_4\,H_5\,O,\,N\,O_3$.
Pelargonic ether,	$C_4\,H_5\,O,\,C_{18}\,H_{17}\,O$.

END OF VOLUME ONE.

CHEMISTRY

THEORETICAL, PRACTICAL, AND ANALYTICAL,

AS APPLIED AND RELATING TO

THE ARTS AND MANUFACTURES.

There are qualities in the products of Nature yet undiscovered, and combinations in the powers of Art yet untried. It is the duty of every man to endeavor that something may be added, by his industry, to the hereditary aggregate of knowledge and happiness.—DR JOHNSON

FUEL——NATURE AND PROPERTIES OF CALORIC.

FUEL.—*Combustible*, French; *Brennstoff*, German; *Fomes*, Latin.—The importance which must have been attached in every age, from the earliest period of human existence, to fire, and the necessity which has ever impelled mankind to provide it, not so much for purposes of luxury, as an absolute essential, to enable them to counteract the effects of climate and other external influences which affect the frame, are sufficient, apart from any other consideration, to impress every one with a sense of its usefulness. It is not in reference to these primary applications, however, that the full value of fire, or the extent of its influence, will be understood, but only when it is studied in connection with the various natural and artificial transformations of matter which it produces.

Nations, however rude or barbarous they might have been, always made use of fire: Firstly, as a means of preservation; Secondly, as a source of comfort or luxury; and lastly, as a destructive agent. The history of its application in relation to these three objects would offer a comprehensive view of the advance of civilization. Not only do the attributes of fire exert a gigantic influence in the various social requirements, but in the most minute as well as the most elaborate changes which take place in nature. Heat and light, indeed, seem to be the life-giving principles of the material world, and are not less essential to man in subduing matter to his service.

Among the material sources of heat, all the substances chemically termed *combustible*, such as carbon, sulphur, phosphorus, potassium, iron, *et cetera*, may be regarded as particular kinds of fuel, although the name is usually restricted to organic products of ligneous origin, such as woody matters, coal, peat, and the like.

As the consideration of fuel is intimately associated with heat, and as this is a subject of great practical importance, it will be necessary to enter into somewhat lengthened details in regard to the nature of caloric—the term applied to the substance or cause of heat, in contradistinction to the sensation which it produces. This theoretical inquiry is essential to a full understanding of various processes and instruments mentioned in the present work, and more especially is it indispensable to a complete elucidation of the nature and action of fuel; or, in other words, of those substances employed to generate that principle which constitutes the great agent, not only in impelling machinery, but in most manufacturing operations. The Editor will, therefore, make no apology for entering here at considerable length into a preliminary exposition of the nature of heat or caloric.

NATURE AND PROPERTIES OF CALORIC.—Of the three imponderables—caloric, light, and electricity—caloric is that which produces the sensation of heat or warmth in animal bodies. It exists, however, in considerable quantities, even when it cannot be distinguished by this test.

Substances communicate a warm sensation when their contained heat exceeds that of the part of the body which touches them; and they are said to be cold when the heat of the latter is greater. Hence it is evident that heat and cold are merely relative terms, and do not indicate the actual amount of caloric which is contained in any body. This can be readily proved by exposing the two hands to unequal degrees of temperature, and then bringing them in contact with a body containing an intermediate quantity; the heated hand will experience the sensation of cold, and the other of heat; that is to say, the same substance will communicate the sensation of heat or cold, according to the temperature of the part of the body touching it.

Caloric is self-repulsive, and eminently destroys cohesion, because it induces the particles of matter to separate to a greater or less distance, according to the amount of it which combines with them—thus producing what is termed *expansion* or *dilatation*. It pervades and penetrates all bodies, however compact they may be, and seems to be in constant intercommunication between them, more especially if they are possessed of it in unequal quantities. In its passage from any one body to surrounding objects, it emanates in direct lines with a velocity hitherto undetermined, but supposed to be equal to that of light. Its intensity, also, diminishes in the ratio of the square of the distance from the heated body. Thus, if at the distance of one foot from the source of heat the effect be accounted unity, at two feet it will be only one-fourth as much, at three only one-ninth, and so on. Heat may be conveyed from one body to another in three ways: firstly, it may pass from one particle to another when the substances are in contact; secondly, it may be emitted in direct lines to a distance; and, thirdly, it may be received after passing through another body which offers little resistance to it. In the first of these cases, it is said to be *conducted*; in the second, *radiated*; and in the third, *transmitted*. In many of its properties it resembles light—more especially in the facility with which it is reflected and refracted. The phenomena of dew, wind, frost, snow, and other atmospheric changes, are consequences of the unequal amount of caloric combined with water.

Sources of Caloric.—Among the acknowledged sources of heat—namely, the sun, electricity, chemical and mechanical action—some enumerate vital action; but this may be regarded as included in the preceding list, for its operations may be referred to the united effects of chemical and mechanical action.

The heat of the sun has been approximately estimated by Pouillet, as between 2662° and 3202° Fahr. When the rays of this luminary are concentrated either by lenses or reflectors, a great amount of caloric may be brought to operate on bodies at a considerable distance. Buffon ignited a board of tarred beech with forty reflectors, at a distance of sixty-six feet; with the power of one hundred and twenty-eight mirrors he set on fire a tarred pine plank, which was one hundred and fifty feet distant. Pieces of coin and other metallic matters were readily melted by this means.

Electricity supplies a heat so intense as to be capable of fusing and even volatilizing matters which, under ordinary circumstances, resist the action of the hottest furnace. Indeed, by galvanism, the highest temperature hitherto obtained has been produced.

Chemical action is, next to the sun's rays, the commonest and most useful source of heat, and the methods of generating it in this manner are various; but that which is best known and most frequently resorted to is combustion. By *combustion* is usually understood that change which a body undergoes on being ignited in the air, and by which light and heat are evolved, whilst the substance itself disappears. Chemically considered, however, combustion is the effect of the union of two or more elements, whereby heat is always disengaged, though light is not a necessary consequent in every instance. Thus, in numerous chemical combinations, considerable quantities of caloric are set free, unattended with luminousness. Animal or vital heat is generated principally by the chemical changes which the food as well as the components of the body are constantly undergoing; and the movements of the members contribute to its more rapid production.

Finally, mechanical action, either by percussion or friction, is capable of disengaging heat from bodies in large quantities. For instance, if a bar of iron be struck with a hammer, a certain amount of caloric will be evolved at every stroke; and by vigorously continuing the action the bar may be made red-hot. But after a rod of metal which has been rendered incandescent by this means has once cooled, no amount of mechanical force is afterwards sufficient to bring it again to a glow, unless it be heated in the fire and allowed to cool. This is owing to the circumstance, that the metal cannot secrete in its condensed state as much latent heat as would be necessary to raise its temperature when further compressed; for the evolution of heat by percussion appears to depend upon the compression of the particles of the body struck. Berthollet measured the amount of caloric emitted from the strokes of a coining-press; he found that, at the first stroke, it gave off 17·3°, at the second 7·5°, and at the third only 1·9°.

Friction is another mechanical means of producing or developing caloric. Instances of this are familiar to engineers, and workers in metal who are engaged in boring, filing, *et cetera*. Even the rubbing of one piece of ice against another may be made to produce an evolution of heat sufficient to melt both, and this will take place more or less quickly according to the amount of force applied in the friction. Count Rumford ascertained that the heat liberated in boring a piece of cannon seven and a half inches in diameter, the instrument making thirty revolutions per minute under a pressure of ten thousand pounds, was sufficient to boil eighteen pounds of water in two hours and a half. If a bar of steel be forcibly struck against a piece of flint or other hard body, the caloric which is set free will be sufficient to cause the combustion of the particles of the metal which are disengaged, and which are seen to fly off in sparks.

Expansive Action of Caloric.—The effects of caloric upon matter are various; but that which is most important, and which will require to be considered first, as affording a convenient measure of its intensity, is its *expansive action*. The distribution of matter into aeriform, liquid, and solid bodies depends on this principle. Many bodies possess the quality of uniting with heat and retaining it to such an extent, that they remain permanently liquid or gaseous, whilst other compounds, having less of the same principle, are solid at ordinary temperatures. In rendering solid bodies aeriform and liquid, the self-repulsive action of the heat overcomes the cohesive force with which the particles were held together, and separates them to a certain distance, dependent upon the amount of caloric absorbed. When a bar of brass strongly heated is placed upon another one of a different kind, but which is an imperfect conductor, for instance lead, the repulsive action of heat will be shown by the evolution of sound. This happens in consequence of caloric being communicated by the heated metal to the lead in contact with it, but not being immediately conducted to other particles of the latter metal, repulsion follows, and the hot body is thrown out of close union; descending, however, by the force of gravity, it again comes in contact with the lead, or nearly so. This contact is immediately broken off, and again renewed, the movement thus continuing in rapid succession till the brass cools. The vibration gives rise to musical sounds. Baden Powell ingeniously measured the force of the self-repulsion of heat by means of colored rings. A flat and convex glass plate were strongly pressed together, and the colored rings formed by the refraction of light from the thin stratum of air between, afforded him the means of estimating the repulsive force; for when heat was applied to the lower plate, the rings altered and closed in towards the centre, showing that the glass plates receded from one another. Now, as each of the annular colors has a certain determinate thickness, it is evident that the degree of repulsion may be ascertained from the narrowing which occurs in the breadth of the rings as the temperature rises.

The expansion or dilatation produced in bodies by heat is a familiar phenomenon. Very great difference exists, however, as to the extent to which divers substances are affected by the same amount of heat. In such compounds as are permanently gaseous, no opposition is offered to the distending power of the combined caloric, and the result is, that these dilate in a regular and uniform ratio, no matter how hot or cold they may be when the caloric is communicated. It is different with solids and liquids, in which the resistance offered by the varying force of cohesion must first be overcome before any discernible repulsion of the particles succeeds. Where this opposing force is great, it is evident that a much larger amount of heat will be required to distend them. Hence the difference in the rate of expansion of bodies produced by this agency.

The Thermometer.—The thermometer, or heat-measurer, is constructed upon the principle of the expansion of bodies by caloric. It consists, in its common form, of a glass tube terminating in a bulb containing mercury or some other fluid, which fills the bulb and part of the tube; and the rise or fall of the fluid in the tube, according as the mass of it in the bulb expands or contracts, indicates the changes of temperature in the surrounding medium. This most indispensable instrument was not known previous to the sixteenth century, and, at its first introduction by the Florentine academicians, its indications were not very trustworthy. At first, the change of the amount of caloric was estimated by the expansion of air; but this, although in common with other aeriform fluids more regular than liquids or solids in its alteration of volume by increased or diminished temperatures, offered so much inconvenience in the wide extent of its range, besides being largely affected by the varying pressure of the atmosphere, that it was found necessary to substitute another fluid. Various liquids, such as linseed oil and spirit of wine, were tried with good effect; but, for general purposes, mercury was found to be the most suitable. The range between its points of solidification and ebullition is greater than that of any other known fluid; it is also a good conductor of heat, and is, consequently, rapid in its indications, and sensitive to sudden changes of temperature. It is true that it experiences, like other fluids, as will be explained afterwards, a constantly increasing rate of expansion as the temperature rises, but between the freezing and boiling points of water this irregularity is so minute, as to be really of little or no moment even in very accurate investigations; indeed, the slight deviation which takes place is nearly compensated by the glass, which expands in much the same proportion as mercury.

There are three varieties of this instrument, differing merely in the notation. Fahrenheit, whose thermometer is generally used in this country, fixed the zero of his scale at the temperature of a mixture of snow and salt, and divided the interval between this and the boiling point of water into two hundred and twelve equal parts or degrees, so that on this scale water freezes at 32°, and there are 180° between its freezing and boiling points. Celsius, in constructing his modification of the thermometer, assumed as the zero of his scale the freezing point of water, and, proceeding on the decimal principle, divided the interval between this and the boiling point into one hundred equal parts, so that on this scale the point of ebullition is indicated by 100°. Hence, his instrument, which is used extensively on the Continent, has been called the Centigrade. In Reaumur's scale, as in the Centigrade, the freezing point is the zero; but the distance between the freezing and boiling points is in Reaumur's divided into 80 equal parts, instead of 100, so that on this scale the boiling point of water is at 80°. In each of these thermometers the degrees of temperature under the zero are indicated by the sign *minus*. Thus, —15° Fahr. indicates fifteen degrees of that scale below the temperature of a mixture of snow and salt; while the same notation on the Centigrade or Reaumur scale signifies a temperature fifteen degrees of the one or the other of these scales below the freezing point of water.

By very simple formulæ, the degrees of any of these thermometers may be converted into the equivalent of the others. The same distance is divided in the three thermometers into 180° in Fahrenheit's, 80° in Reaumur's, and 100° in the Centigrade. Now, dividing by twenty, it will be seen that these numbers are in the ratio of 9 : 4 : 5; or, in other words, nine degrees of Fahrenheit's scale are equivalent to four degrees of Reaumur's, and five of the Centigrade. Hence, indicating the respective thermometers by the initials F., R., C., the length of a degree in each will be as follows:—

$$1^\circ\ \text{F.} : 1^\circ\ \text{R.} : 1^\circ\ \text{C.} :: \tfrac{1}{9} : \tfrac{1}{4} : \tfrac{1}{5}$$

But the temperature is measured by the number of divisions contained in equal portions of the stem of the respective thermometers. Now, the zero point of Fahrenheit's is 32° below freezing point. If, therefore, F.° — 32, R.°, C.°, indicate the same temperature on each of the three thermometers, one has the proportion:—

$$\text{F.}^\circ - 32 : \text{C}^\circ : \text{R.}^\circ :: 9 : 5 : 4$$

whence result the following equations for converting one scale into another:—

$$4\,(F.^\circ - 32) = 9\ R.^\circ$$
$$5\,(F.^\circ - 32) = 9\ C.^\circ$$
$$5\ R.^\circ = 4\ C.^\circ$$

or,

$$\tfrac{1}{9}\,(F.^\circ - 32) = \tfrac{1}{4}\ R.^\circ = \tfrac{1}{5}\ C.^\circ$$

The divisions principally used are those of Fahrenheit and the Centigrade, and the equations for passing from the indications of the Centigrade to those of Fahrenheit, and *vice versâ*, are—

$$F.^\circ = 32 + \tfrac{9}{5}\ C.^\circ$$
$$C.^\circ = \tfrac{5}{9}\ (F.^\circ - 32)$$

that is, add thirty-two to nine-fifths of the number indicated on the Centigrade, and the result is the number which would be indicated by Fahrenheit; subtract thirty-two from the number indicated by Fahrenheit, and five-ninths of the remainder is the number which would be indicated by the Centigrade.

When very low temperatures, under —40° Fahr., have to be estimated, a mercurial thermometer cannot be employed, since this metal solidifies at that point; in such cases, alcohol colored by some matter is used in the bulb of the instrument. On the other hand, mercury boils at about 600° Fahr., and, therefore, when very high temperatures are to be estimated, a different instrument, termed the pyrometer, is employed, which will be described in the sequel.

Whatever be the form of thermometer, it is evident that the indications are merely relative, and do not express the actual amount of caloric which a substance contains. The use of the thermometer, therefore, is merely to indicate the sensible heat, or that which is capable of being radiated or communicated from one material to another; and for this purpose it is of most important application in various branches of the arts and manufactures, serving for the guidance of the operatives in numerous processes, to the success of which it is absolutely indispensable.

Expansion of Solids.—The rate of expansion in solid bodies is greatly dependent on their state of aggregation; hence it will be evident that the same amount of caloric will operate differently on different solids, but the effect is more visible in the metals than upon other solid non-metallic substances.

The following table exhibits the rate of expansion of a few solids when heated from 32° to 212°:—

TABLE OF EXPANSION FROM 32° TO 212° FAHR.

Name.	Expansion in length.	Do. in bulk.	Authorities
Zinc, cast, ……	1 in 323		
„ sheet, ……	1 „ 340	1 in 113	Smeaton.
Lead, …………	1 „ 351	1 „ 117	Lavoisier and Laplace.
Tin, …………	1 „ 516	1 „ 172	
Silver, …………	1 „ 524	1 „ 175	
Brass, …………	1 „ 536	1 „ 179	
Copper, ………	1 „ 582	1 „ 194	
Gold, …………	1 „ 682	1 „ 227	
Bismuth, ………	1 „ 712	1 „ 239	Smeaton.
Iron, …………	1 „ 846	1 „ 282	Dulong and Petit.
Antimony, ……	1 „ 923	1 „ 307	Smeaton.
Tempered steel,..	1 „ 926	1 „ 309	Lav. and Lap.
Palladium, ……	1 „ 1000	1 „ 333	Wollaston.
Platinum, ……	1 „ 1131	1 „ 377	Dulong and Petit.
Glass without lead,	1 „ 1148	1 „ 382	
Flint glass, ……	1 „ 1248	1 „ 416	Lav. and Lap.

From the foregoing results it is evident that the expansion in bulk is about three times as great as the linear expansion; or, in other words, by multiplying the latter by three, the product will approach closely to the increase in bulk. It must be observed, however, that the expansion is not uniform for equal increments of temperature, for all bodies tend to expand more as the heat reaches a high degree. This is especially the case with metals; hence it is that mercurial thermometers are not well adapted for measuring degrees of temperature much higher than that of boiling water, owing to the increase of the metal at high heats being greater than at low. The rates of expansion in mercury from 32° to 572° are—one in 55·08 between the freezing and boiling points of water; one in 54·61 between the latter and 392°; and one in 54·01 between this and 572°.

The extent to which glass expands when heated within the same range is given in the table annexed:—

Temperature by air thermometer.	Mean absolute dilatation of glass for each degree.	Temperature by thermometer made of glass.
From 32° to 212	$\frac{1}{69660}$	212°
„ 32° to 392	$\frac{1}{65340}$	415·8°
„ 32° to 572	$\frac{1}{59220}$	667·2°

Most solids return to their original volume when they have parted with the caloric which caused the distention of their particles; some, however, are incapable of doing so, and are permanently elongated or enlarged every time they are subjected to the influence of a high temperature. Such is the case, more especially, with zinc and lead—the particles of which, in sliding over each other, are supposed to possess an amount of adhesive friction which prevents their retraction to the full extent they had expanded.

The expansion or contraction of bodies, occasioned by an increase or diminution of temperature, takes place with enormous force. The amount of this has been estimated by BARLOW, who found that a bar of metal, of one square inch section, is elongated one ten-thousandth of its length by receiving an addition to its temperature of 16°; to produce the same effect mechanically would require a ton weight to be suspended from it, or the application of an equivalent force. A careful attention to this subject is indispensable in the sciences of engineering, horology, *et cetera.* It has been found that within the usual range of the variation of the temperature of England throughout the year, a bar of wrought-iron, ten inches long, will expand about two hundredths of an inch. Were both its extremities secured firmly to other objects, this change would exert a force, tending towards their removal, of fifty tons to the square inch; hence it is to be observed that where beams of wood are to be replaced by iron ones, care should be taken that room for occasional expansion should be allowed them, otherwise very ruinous consequences might result. From the numerous and varied uses to which iron is now applied, this is a subject of very great importance. An accurate calculation must be made, and the structure so formed, as that the expansion or contraction of the metal shall not endanger its stability.

A very ingenious application of the power obtained by the enormous force of the contraction of metals was made by MOLARD, to secure the Museum of Arts and

Manufactures in Paris, by restoring the walls, which were giving way outward owing to the weight of the roof. His method was to insert bars of iron horizontally through the building, so as to protrude a little from the walls at each side. Heat was then applied by lamps suspended over the whole length of the bars, and the metal expanded to some extent, after which iron nuts were firmly screwed on the bars at both ends, and tightened to the wall as much as possible; the heat being now removed, the metal began to contract, and in doing so, it drew the nuts closer together, which had the effect of bringing the walls nearer to the perpendicular. By a repetition of the heating of the bars, and again tightening the nuts or plates, the bulges were entirely removed and the walls were restored to their vertical position. In many of the ordinary arts of life, a similar advantage has been taken of the effect of heat upon bodies to render peculiar service; the wheel-wright, by heating the tire and fitting it on in an expanded state, and then allowing it to contract, insures the firmness and durability of the wheel; the cooper, in like manner, heats the hoops of his casks, *et cetera*, when fitting them in their proper place, so that when they cool they may bind the staves more firmly; and the boiler-maker uses red-hot rivets as well for facilitating their plating, as for binding the sheets of metal more tightly by their subsequent contraction on cooling.

The sudden application of heat to many bodies is productive of fracture, owing to a partial expansion of the part heated, while the part not so affected refuses to yield. This is frequently seen in glass and cast-iron plates. Indeed, the most delicate part of the glass-maker's business, as will be seen in a future article, is the annealing; or, in other words, the exposure of the goods to a gradual cooling, which renders them less liable to crack when exposed to sudden changes of temperature.

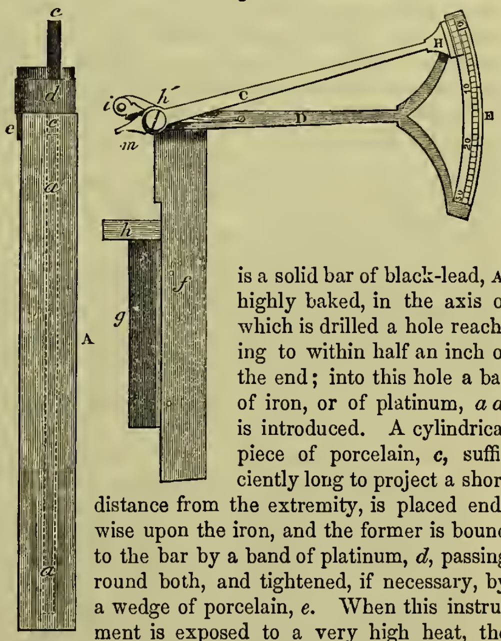
A tabular statement of the rate of expansion of a few of the metals is subjoined, with a comparative view of the results when the temperature is measured with the air thermometer, and with one constructed of the metals under experiment:—

Temperature by air thermometer.	Mean dilatation of iron for each degree.	Temperature by iron rod thermometer.	Mean dilatation of copper for each degree.	Temperature by copper thermometer.	Mean dilatation of platinum for each degree.	Temperature by platinum thermometer
212°	$\frac{1}{50760}$	212°	$\frac{1}{34120}$	212°	$\frac{1}{67860}$	212°
572°	$\frac{1}{40678}$	702°5	$\frac{1}{31860}$	623°8	$\frac{1}{65340}$	592°9

In estimating the temperature at high degrees by a mercurial thermometer, the observations made as to the rise of the metal indicate only the difference between the expansion of the glass and that of the metal, which, in ordinary cases, is supposed to be uniform; but owing to the increased expansion which the mercury experiences at a high temperature, 572° on the air thermometer corresponds with 586° on the mercurial one. The same temperature estimated by glass alone would be indicated by 667°, thus showing that the dilatation of the glass counteracts the expansion of the fluid metal. Considerable difference will be observed in the table between the indication of the air thermometer and that which is found by measuring the expansion of bars of metal; so that at high temperatures, which liquids and gaseous bodies cannot be employed to measure, the true indication of heat, as compared with the air thermometer, is somewhat difficult to ascertain. A further obstacle stands in the way, inasmuch as the rate of expansion in metals and most solid bodies is unequal. M. **Breguet** contrived to overcome this by constructing a solid thermometer, composed of a compound ribbon of three metals—gold, platinum, and silver—rolled out very thin and coiled spirally. The upper end of these was fixed, and the lower one attached to an index which described an arc, as the helix twisted or untwisted, by the greater expansion or contraction of the silver band over the platinum one. By graduating the range of the index, and finding the value of the indications by comparing them with those of a standard thermometer, the instrument was completed.

The Pyrometer.—When the temperature is very high, such as that at which the more infusible metals melt, or of a reverberatory or wind furnace, the common thermometer is unavailable, and other instruments for estimating the heat have been invented, which are called *pyrometers*. Of these, **Daniell**'s register pyrometer, represented in Fig. 1, is the most accurate. It consists of two parts, namely, the register and the scale. The register is a solid bar of black-lead, A, highly baked, in the axis of which is drilled a hole reaching to within half an inch of the end; into this hole a bar of iron, or of platinum, *a a*, is introduced. A cylindrical piece of porcelain, *c*, sufficiently long to project a short distance from the extremity, is placed endwise upon the iron, and the former is bound to the bar by a band of platinum, *d*, passing round both, and tightened, if necessary, by a wedge of porcelain, *e*. When this instrument is exposed to a very high heat, the whole increases in bulk, in proportion to its intensity; but the rate of expansion of the metal and of its casing being unequal, the porcelain cylinder, *cc*, will be protruded to the extent of the difference.

Fig. 1.



To measure the length of the protruded portion, the scale is applied. This consists of two brass rules, *f*, *g*, joined together by screws, to form a right angle, and fitting exactly upon the sides of the register. The plate, *h*, rests on the shoulder of the bar, A, formed for the platinum band. At the extremity of the rule nearest this, an arm, D, movable upon its centre, *i*, is fixed; and at the other an arc of a circle, E, graduated into degrees and thirds of degrees. Upon the latter, at *h′*, is another lighter arm, C, carrying upon the end of its longer limb a nonius, H, which moves upon the face of the arc, E, and subdivides the graduations into minutes. The other end of this arm protrudes beyond the centre of motion, and carries a steel knife-edged bar, which fits into the notch cut for it in the termination of the index.

The index bar is pressed firmly down upon the metal encased in the black-lead, and securely fixed there by the wedge and band of platinum; the bar is then nicely adjusted in the angle formed by the two rules of the scale; the plate, *h*, firmly held against the shoulder, and the knife edge, *m*, resting in the notch in the index bar; the position of the latter is now noted on the scale, and after the register has been heated and allowed to cool, the scale is again applied and the result observed—the difference is the value of the expansion of the metal bar. By comparing this with the indications given by a mercurial thermometer between any two points, say that of the freezing and boiling of water, an expression in degrees of Fahrenheit's scale may be given to any degree of artificial heat measurable by the instrument.

DANIELL, with this apparatus, obtained the following results, in which the expansion is shown at three stages:—

1,000,000 parts at 62°.	At 212°.	At 662°.	At fusing point.	
Black-lead ware,	1,000,244	1,000,703		
Wedgwood ware,	1,000,735	1,002,995		
Platinum,	1,000,735	1,002,995	1,009,926	maximum, but not fused.
Iron—wrought,	1,000,984	1,004,483	1,018,378	to the fusing point of cast-iron.
Iron—cast,	1,000,893	1,003,943	1,016,589	
Gold,	1,001,025	1,004,238	——	
Copper,	1,001,430	1,006,347	1,024,376	
Silver,	1,001,626	1,006,886	1,020,640	
Zinc.	1,002,480	1,008,527	1,012,621	
Lead,	1,002,323	——	1,000,972	
Tin,	1,001,472	——	1,003,798	

Expansion of Liquids.—In liquids, the expansion produced by heat is much more marked than in solids; they also differ among themselves in the amount of expansion produced by equal increments of heat. The most volatile liquids, or those of which the boiling point is low, are found to be the most expansible under the influence of an increase of caloric, as may be observed from the appended table, showing the comparative increase in volume of several liquids when heated from 32° to 212°:—

Water,	0·0466	Dalton.
Saturated solution of chloride of sodium,	0·0500	"
Concentrated sulphuric acid,	0·0600	"
Hydrochloric acid, specific gravity 1·137	0·0600	"
Nitric acid, specific gravity 140	0·1100	"
Alcohol, specific gravity 0·817	0·1100	"
Ether,	0·0700	"
Oil of turpentine,	0·0700	"
Fat oil,	0·0800	"
Mercury,	0·02000	"
"	0·01887	Cavendish.
Mercury,	0·01848	Lavoisier and Laplace
"	0·01818	Hallstrom.
"	0·01801	Shuckburgh.
"	0·01800	Petit and Dulong.
"	0·01786	Deluc.
"	0·01665	Roy.

A difference in the seething point of liquids, however, does not always show a corresponding variation in their expansion, as was long ago proved by LAVOISIER with regard to alcohol and bisulphide of carbon, two liquids differing in their boiling points by 57°, yet the rate of expansion is the same in both for each increase of an equal number of degrees of heat, reckoned from their respective boiling points. PIERRE found similar results in his researches upon liquids of analogous composition, such as the bromides and iodides of ethyl and methyl. This relation, however, does not appear between some of the isomeric bodies examined, as may be seen from the annexed table, showing the

CONTRACTION FROM THE BOILING POINTS:—

Name of Liquid.	Boiling point. Fahr	Temperature equidistant from the boiling point of each group.	Interval between the preceding temperatures.	Volume at boiling point.	Volume at equidistant temperatures
FIRST GROUP.					
Sulphide of carbon,	118·22°	22·72°	140·94°	1	0·913099
Alcohol,	172·94	32	140·94	1	0 914452
Wood spirit,	151·34	10·4	140·94	1	0·905819
SECOND GROUP.					
Bromide of ethyl,	105·26	32	73·26	1	0·944375
Bromide of methyl,	55·4	17·86	73·26	1	0·944575
THIRD GROUP.					
Iodide of ethyl,	158	32	126	1	0·918704
Iodide of methyl,	110·84	15·16	126	1	0·916643
FOURTH GROUP.					
Formiate of oxide of ethyl,	127·22	20·12	107·1	1	0·910223
Formiate of oxide of methyl,	139·10	32	107·1	1	0·918750

With reference to the second law which governs the expansion of liquids—namely, that they are progressively more expansible at higher than at lower temperatures—it is to be remarked, that in this respect considerable difference exists between different liquids; and in mercury the higher expansion at higher temperatures is less than in any other fluid body. Hence, it is better adapted than any of them for the construction of thermometers. The expansion which takes place in each of the substances enumerated in the following table, between the freezing and boiling points of water at the ordinary pressure, is represented by one hundred parts, and the increase which equal increments of heat produce above 212° is proportionally estimated:—

		Dulong and Petit.			
Air.	Mercury.	Platinum.	Copper.	Iron.	Glass.
0	0	0	0	0	0
100	100	100	100	100	100
150	151·3				
200	204·6				
250	255·1				
300	314·15	311·6	328·8	372·6	352·9
350	360				

Water, within the range of its solidifying point and that at which it becomes an elastic vapor, is subject to very great irregularities. The general law, as before expressed, is, that heat exerts an expansive force upon all bodies; but, within a certain range, water becomes an exception. If this liquid be taken in the solid state, or at the temperature of 32°, before it has solidified, and caloric be communicated to it, instead of expanding, it actually contracts till it marks about 39·4°, at which it has attained its greatest density. Above this, it expands in the same ratio that the contraction took place for an equal number of degrees, but beyond that point it obeys the general law.

Count **Rumford** found the contraction of water for every 22·5° from the boiling to the freezing temperatures to be as follows, namely:—

In cooling,	22·5° from	219° to 189·5°,	2000 measures of water	contracted	18	measures
"	"	189·5° to 167°,	"	"	16·2	"
"	"	167° to 144·5°,	"	"	13·8	"
"	"	144·5° to 122°,	"	"	11·5	"
"	"	122° to 99·5°,	"	"	9·3	"
"	"	99·5° to 77°,	"	"	7·7	"
"	"	77° to 54·5°,	"	"	3·9	"
"	"	54·5° to 32°,	"	"	0·2	"

The dilatation of water, when reduced in temperature below 39·4°, serves a purpose of the greatest consequence in the economy of nature—namely, in preventing the transmission of cold beyond the surface of the water in very rigorous seasons, and preserving the chief bulk of the fluid at such a temperature as is congenial to the life of the animals that inhabit it. The fusible alloy of **Rose** possesses properties in some respects analogous to water. This substance increases in bulk till it reaches about 111°, after which it contracts when its temperature is being raised from this to 156°, the point of its greatest density, and at which its bulk is less than when at the freezing point of water; after this, however, it continues to expand till it reaches its fusing point at 201°.

Expansion of Gases.—The third class of bodies to be considered in relation to the expansive force of heat, are gases. All these being at ordinary temperatures in a state in which the atomical aggregation manifests a highly repulsive tendency, it is evident that they will be influenced to a greater extent by caloric than either of the foregoing classes. A remarkable coincidence or uniformity, however, is found to exist among the different members of this class; and, knowing the rate of expansion of one when combined with a certain amount of caloric, the same may be taken as the expansive power of the other permanent gases and elastic vapors when subjected to an equal increase of temperature. By former investigations, this was found to amount to about three hundred and seventy-five parts in a thousand of air, when heated from the freezing to the boiling point of water; later researches, however, have shown that the true expansion of air within these limits is three hundred and sixty-six parts, or $\frac{1}{491\cdot2}$ of the whole for each degree of Fahrenheit's scale. Below the freezing and above the boiling point of water, the expansion is in the same ratio. A volume of gas measuring four hundred and ninety-one parts at 32° Fahr. expands, for every degree of heat additional, one part; so that at 60°—that is, with an increase of 28° of the thermometric scale—the volume becomes five hundred and nineteen parts. This ratio continues as long as the temperature rises, so that when the whole is heated to $523° = 32° + 491°$, or in other words, is raised through as many degrees as there are original divisions in the bulk of the liquid, the volume will be doubled; and in proportion as multiples of this increase of temperature are applied, so will the air dilate to three, four, or more times its bulk. It was found, however. by **Magnus** and **Regnault** that the operation of this law is not perfectly uniform, especially with reference to the easily liquefied gases, which are more expansible than air when exposed to equal increments of heat, as the following table will show:—

	Expansion upon one volume from 32° to 212°.	
Names of Gases.	Magnus.	Regnault.
Atmospheric air,	0·366508	0·36650
Hydrogen,	0·365659	0·36678
Carbonic acid,	0·369087	0·36896
Sulphurous acid,	0·385618	0·36696
Nitrogen,	———	0·36682
Nitrous oxide,	———	0·36763
Carbonic oxide,	———	0·36667
Cyanogen,	———	0·36821
Hydrochloric acid,	———	0·36812

A sensible increase in the rate of expansion is also found when the gas is submitted to pressure, compared with that which takes place when it is in a rarefied state.

Conduction and Convection of Heat.—Another point of great importance is the comparative facility with which heat is conveyed or conducted through different bodies. When caloric comes in contact with solids or liquids, it enters into them and traverses from molecule to molecule, till it has permeated the whole. This property of heat, although by many supposed to be due to radiation, owing to the particles of matter not being in absolute contact, is, however, generally acknowledged to be due to a distinct action —that of conduction.

Different substances vary considerably in regard to the freedom with which caloric passes through them—that is to say, in their conducting power; and many very useful applications have been made of this property in the arts and sciences. It is upon this principle that nature protects every species of animal and vegetal life against the injurious influence of meteorological changes. The differences observed in the physical appearance of man and of other races of animals, according to their position on the globe, are ordered in conformity with the laws which regulate the conduction of heat; and the means adopted by various nations for shielding their persons from the opposite extremes of heat and cold, as also the covering of every indigenous species of living being, no matter of what class or kind, are all most admirably suited to the state and condition in which they live. The colored cuticle of the African, whose existence is ordained under a burning sun, is not less requisite for radiating or allowing a free passage for the heat he has to endure, than is the white skin of the European to prevent the sudden ingress and egress of caloric to or from the body. Not only does the natural state give proof of this wise disposition in the human species: it is still more manifest in the lower orders of creation, which have not like man the reasoning power that enables him to provide for the exigencies of his condition; hence they are usually defended by a non-conducting coat of fur or feathers, protecting them from sudden transitions of temperature.

Dense and heavy substances are generally good conductors; light and porous bodies have this property only imperfectly. This may be proved by taking metallic rods, to which small balls of wax are attached at different distances, and introducing one end of them into the flame of a candle. As the heat proceeds from one particle of the metal to another, its progress may be measured by the falling off of the balls successively, owing to the wax being melted by the heat. But if cylinders of wood, glass, or wax be heated in a similar manner, a different result will be observed, owing to the latter being bad conductors of caloric. A practical application of this fact is seen in metallic instruments intended to be used while hot; these are invariably furnished with handles of some badly-conducting material—such as wood or glass—to protect the hand from being scorched.

Despretz instituted a series of experiments for determining the conducting power of metals. His method was to drill holes, at the distance of 3·93 inches apart, in bars of the metal of an equal and determinate thickness; into these holes thermometers were inserted, and the ends of the metals then applied to a heating medium. Caloric was allowed to traverse the bars as long as the thermometers continued to indicate an increase in the temperature. The observations made in this way furnished the annexed numbers:—

Gold,	1000·0
Silver,	973·0
Copper,	898·2
Iron,	374·3
Zinc,	363·0
Tin,	303·9
Lead,	179·6
Marble,	23·6
Porcelain,	12·2
Fire-clay,	11·4

Platinum is a singular exception to the general rule above stated; for, unlike silver, copper, or such other dense bodies, a wire of this metal may be held in the hand and heated to redness at one end, even when only a few inches in length. Glass, although a substance of moderate density, is likewise a bad conductor. The conducting power of a body is much diminished by its being pulverized; thus, metallic filings are worse conductors than bars of the same material; pounded glass and sawdust are also inferior in this respect to solid rods of glass or wood. Charcoal conducts heat very feebly; as also sand, and a number of other bodies, all of which on this account are of importance in cottage architecture, and for other purposes, in which it is desirable to provide against sudden changes of temperature.

The following are the results which Mr. Hutchinson obtained in his researches on the conducting powers of building materials. The substances are arranged in the order in which they resist the passage of heat, the best non-conductors being placed first:—

Name of substance.	Conducting power referred to that of slate, equal 100.
Plaster and sand,	18·70
Keene's cement,	19·01
Plaster of Paris,	20·26
Roman cement,	20·88
Beech wood,	22·44
Lath and plaster,	25.55
Fir wood,	27·61
Oak wood,	33.66
Asphalte,	45·19
Chalk—soft,	56·38
Napoleon marble,	58·27
Stock brick,	60·14
Bath stone,	61·08
Fire brick,	61·70
Painswick stone, H.P.,	71·36
Malm brick,	72·92
Portland stone,	75·10
Lunelle marble,	75·41
Bolsover stone, H.P.,	76·35
Norfal stone, H.P.,	95·36
Slate,	100·00
Yorkshire flag,	110 94
Lead,	521·34

Besides the use which is made of the property of non-conduction in architecture, there are other departments of the arts and manufactures in which it subserves important purposes. Thus it is applied with good effect in constructing fireproof edifices or apartments, and in the manufacture of chests and boxes intended to preserve valuable property, legal documents, *et cetera*, from the destructive effects of conflagration.

In the latter case, this is effected by interposing some solid body which is a bad conductor of heat between the interior lining and the exterior frame of the chest. The well-known safes of Milner and Son, of Liverpool, are constructed in this way. The inner chamber is made of stout sheet-iron, firmly secured by riveted bolts to the exterior one, which, by its strength, is calculated to resist fire, and any external violence, either intentional or accidental, to which it is liable. The intermediate chamber is filled with a composition which can scarcely be excelled as a non-conducting material, whilst, at the same time, its heat-absorbing power, or, in other words, its quality of rendering heat latent or insensible, is very great. From repeated testings, at some of which the Editor attended, these articles have been proved capable of withstanding a twenty-four hours' fire of intense heat without allowing the contents to be injured in the least. Fig. 2 is a front view, and Fig. 3 a section of one of these safes. In Fig. 3, the chamber containing the non-conducting material is shown. At one time this consisted almost entirely of clay, sand, and some carbonaceous matters, in the middle of which were metallic tubes filled with water, and hermetically sealed with a fusible alloy. When the heat reached them, the plug of metal by melting allowed the water to flow out, thus moistening the ingredients, and arresting the passage of the caloric. If the fire were prolonged, the moisture would be disseminated in vapor in the inner chamber where the valuables were deposited, and thus would secure them still more perfectly against combustion. The tubes, however, were found troublesome and expensive, and improvements of a simpler nature adopted. According to the specification of Mr. Milner, the ingredients now used are quartz, crystallized carbonate of soda or alum, and the dust of hard woods, all of which are blended in such proportions as that twenty-five per cent. of the whole shall consist of moisture, which is capable of being expelled on the application of heat. The water in this case is exclusively derived from the salts—the carbonate of soda containing sixty-two and the alum fifty-five per cent. of water, which is separated slowly even with the application of a very high temperature.

Fig. 2.

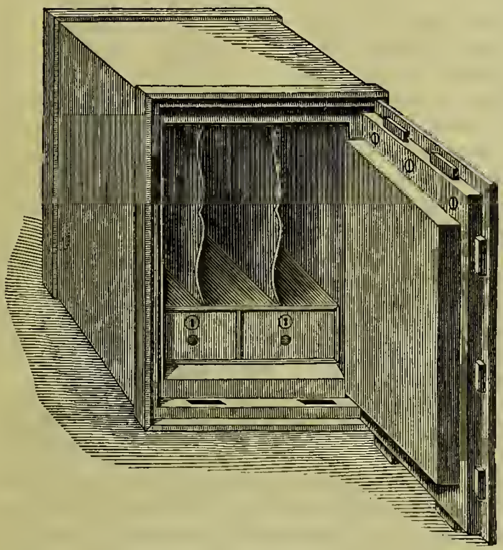
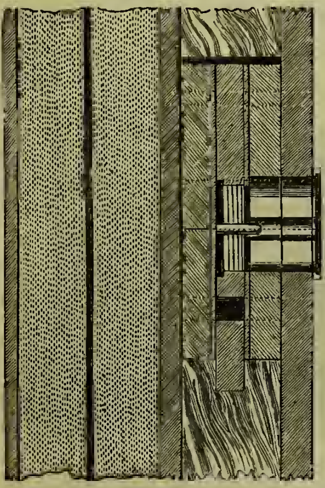


Fig. 3.



The same principle is brought into requisition when the design is to preserve the heat in rooms and prevent it from escaping. In this case, the object is accomplished by constructing double doors and windows: thus enclosing a partition of air, which is a very imperfect conductor of caloric, and, therefore, the heat of the chamber is retained. In a similar manner, fireproof chambers may be made, having, in connection with the space between the double walls, a means for supplying cold air to occupy the place of that which must pass off as the increased temperature expands it. Unless such provision be made, the pressure which the increased tension of the vapor acquires as the heat increases would be apt to burst the walls.

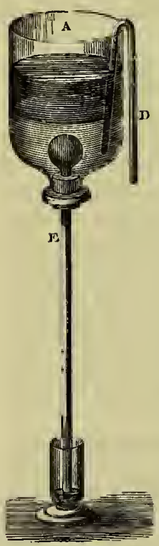
On similar principles great attention is required in selecting the materials employed in the construction of furnaces. To prevent the escape of the caloric, and thus to economise fuel, the hearth and walls of the furnace are invariably compounded of some non-conducting substance, as Stourbridge clay or powdered brick, mixed with a large quantity of powdered charcoal or coke. For the same reason, boilers are imbedded in bricks or clay, and in many boilers the fire is literally enclosed within them, that none of the heat may be lost, but that all may be rendered available for raising the temperature of the water.

Seramont examined the conducting power of crystalline bodies, and proved that, in such as do not belong to the regular system, power varies in different directions according to the inclination of the optic axis of the crystal. De la Rive and Decandolle have, in like manner, shown that the conducting power of wood is different according to the direction in which the heat is transmitted, being greatest in the course of the grain or fibre, and least across it. Tyndall has established the same fact by showing that caloric much more readily traverses from the surface of a log of wood to the centre, than it does in a direction parallel to the annular layers of ligneous matter. In woods, also, as in metals, their conducting power appears to vary with their specific gravity, being least in the lightest kinds; this, however, requires corroboration. Textile fibres which are manufactured into articles of clothing are very bad conductors; but their actual conducting power cannot be exactly ascertained, in consequence of the air which is contained in their pores.

Liquids in general are bad conductors of heat; it was formerly asserted, indeed, by some chemists, that water is an absolute non-conductor; it has been proved, however, that liquids conduct caloric in some measure, subject to the same laws as solids, although, as regards water and other such mobile liquids, very feebly.

The following experiment, among many which might be adduced, will illustrate the weak conducting power of water:—

Fig. 4.



Let the mouth of a bottomless glass jar, A, be closed by a perforated cork, through which the stem of an air thermometer, E, passes. Invert the jar, and pour into it cold water till nearly half-filled; on the surface of this cold liquid, place a cork disc, and then introduce a quantity of warm water colored either red or blue, to distinguish the two portions of liquid. The disc may now be cautiously removed, and the hot water will remain in a distinct layer upon the other. If the heat were conducted through the cold medium, it would act upon the air thermometer by causing the expansion of the enclosed air, and the expulsion of a proportionate quantity of the liquid from the stem; but no such effect is observed. If the cold water be now drawn off from the bottom by means of a siphon, D, it will still be found that no rise of temperature is indicated by the instrument, till the colored liquid comes in contact with the bulb, when the confined air will be expanded, and the tinged liquor in the stem ejected into the vessel into which the thermometer dips. From this it is evident that the conducting power of water is very feeble, and so with other similar mobile liquids. If, however, mercury be substituted for the cold water, and the warm water poured upon it, the effect upon the thermometer is instantaneous. This proves that fluidity is not the cause of the non-conduction of heat by water, and other similar bodies, but that it depends to a certain extent on the nature of the substance itself.

Moreover, the effect observed is very different when, instead of applying caloric at the upper surface, it is communicated to the under part, or to the bottom of the vessel in which the liquid is contained. In this case, the particles in immediate contact with the heat-giving body acquire a portion of caloric, and are expanded. This, by rendering them lighter than the surrounding ones, causes them to ascend; fresh particles succeed, and these rise in a similar manner. Currents are thus determined in the liquid, and caloric is readily communicated to the whole mass. This, however, is not a case of conduction from particle to particle; neither is it due to radiation, which will be afterwards explained; but is the effect of *convection*—that is to say, the actual conveyance or distribution of the heated portion throughout the mass.

Fig. 5.

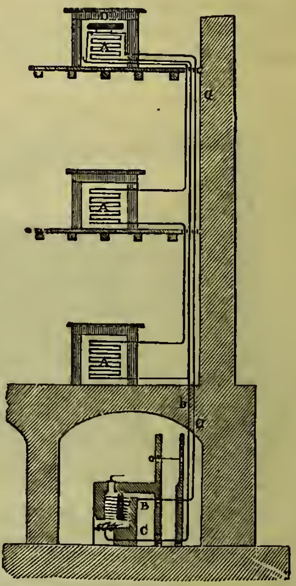
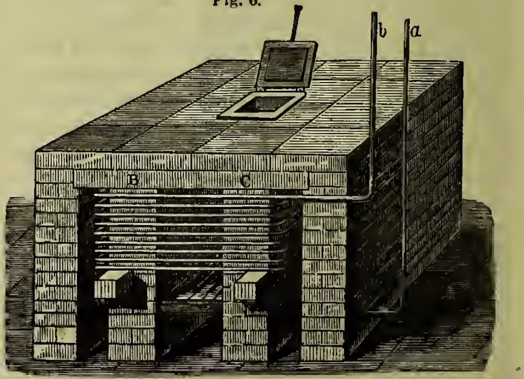


Fig. 6.



Very great benefits are derivable from this property of fluids. It has been advantageously applied in the ventilation of buildings, the hot air rising to the top and escaping, while cool air is injected. It is upon this principle also that Perkins's apparatus for the heating of dwellings is constructed. This is represented in its simplest form in Fig. 5; it essentially consists of an iron pipe one inch in exterior diameter, and half an inch in the bore. This being filled with water and distributed throughout the building, a portion of it is heated in a furnace, and a current is thus established through its entire length. The caloric acquired by the water in its passage through the heated portion of the pipe, is given off by radiation in performing the rest of the circuit, till it returns to be reheated. The several coils, A A A, may represent as many apartments, each embracing a considerable length of pipe; the coil, B C, which is generally about one-sixth of the whole length, and which is represented on a larger scale in Fig. 6, receives the heat of the furnace. The course of the water from this portion is through the pipe, *a a*, which rises till it reaches to the top of the building; here it branches off into several conduits to traverse the different parts of the edifice, all reuniting in the pipe, B, before returning to the furnace. Water is introduced at the open end, D, which is kept tightly plugged while the apparatus is in action; a space, E, is provided in connection with the pipe at the top of the building, to admit of room for the expansion of the heated liquid, and thus prevent the bursting of pipes: its capacity is about one-fifth or one-sixth of the whole.

Apart from the consideration of the useful purposes to which the convection of heat is applied in the arts, a far more important end is served by it in the economy of nature. During the frosts of winter, the process of cooling goes on downward from the surface of the earth and water. The colder water at the top becoming condensed, and consequently heavier than that beneath, sinks and gives place to the latter; this goes on as long as the atmosphere remains at a low temperature, till the water is reduced to its maximum density, a point which it attains at 39·4°. It is a remarkable circumstance, and forms a singular exception to a general law, that water when cooled to this point begins to expand, and consequently remains at the surface. When cooled to 32° it freezes, and during its conversion into ice it experiences a still further expansion, so that the ice, instead of sinking to the bottom, and there accumulating in dense masses, floats on the surface till melted—one of the most wonderful provisions for the preservation of life in the whole economy of nature.

In their mode of conducting heat, gases resemble liquids; that is to say, their power of actual conduction is inappreciable; but by their property of convection, currents are instituted by which the heat is disseminated throughout the mass. To observe this, it is only requisite to hold the hand first at the side of a lighted candle, and then above it, the distance in both cases being equal; it will be perceived that, in the first position, little heat is received, whilst in the second the increase of temperature is immediately obvious, the greater portion of the heat being carried off in the ascending current; which, in gases, is more active than in liquids, owing to their power of expansion being so much greater. The application of these currents of heated air is of great practical importance in the ventilation of dwellings and public buildings. Indeed, in every species of human habitation, provided with a fire-place and chimney, the latter operates as a ventilating apparatus. The heat derived from the combustion of fuel in the grate or on the hearth, dilates the super-imposed atmosphere, and causes its ascent in the shaft, while an influx of air to the fire supplies its place. The transmission of smoke and warm air through the chimney soon raises its temperature, and, on this account, the heat which is received from the fire is retained by the vapor till it passes out at the top. The force of the current or *draught* thus formed will be in proportion to the greater expansion of a column of air of the height of the chimney, than that of an equal column externally. Common air, like other gases, increases one five-hundredth of its bulk for each degree of temperature which it acquires; hence, by ascertaining the internal temperature and height of the chimney, the force of the ascending atmospheric column may be calculated. When it happens that the apartment is very close, and does not admit sufficient air to supply a stream from beneath, it enters at the top of the shaft, and causes a *back* draught. In such cases the chimney is said to smoke, and the remedy usually applied is to open the door or window, so as to admit sufficient air to maintain the current. To avoid smoke, care should be taken in hanging the doors, *et cetera*, that space be allowed for the influx or air, so as to prevent its entrance from above. It is a well-known fact, that in a heated apartment the warmer portion of air rises to the ceiling, and the colder stratum remains underneath; hence it is obvious, that to maintain a proper state of ventilation, apertures must be provided in or near the ceiling, whereby the warm gases may escape. This, however, will prove ineffectual, unless provision be made for the entrance of a corresponding volume of air at or near the floor, to supply the place of that expelled. In large buildings, where the heat eliminated from fires would be ineffectual towards warming them, heated air is used in nearly the same way as the water in PERKINS's method, only that the hot air is distributed in the various apartments through gratings in the floorings or side walls. Dr. REID's apparatus for ventilating St. George's Hall, Liverpool, operates in this way; and several other large enclosures and churches throughout the kingdom are heated on the same principle. The phenomena of winds and oceanic currents are all referrible to the same cause; and, as in the case of ventilating apparatus, so on the large scale of the globe, the streams or currents which are induced by differences of temperature tend to equalize the amount of heat which is received from the sun, to distribute it more uniformly over sea and land, and thus to modify the intensity of cold and heat in climates exposed to opposite extremes of temperature.

RADIATION OF HEAT.—On the whole, it may be laid down as a general law, that air, the gases, water, and fluids generally, with the exception of mercury, are bad conductors of caloric, notwithstanding that it is distributed readily by them in the manner already explained. Although, however, it is the natural tendency of convection to operate upwards, yet, if the hand or the bulb of a sensitive thermometer be placed at some distance beneath a warm body, or on either side of it, an increase of heat will be indicated. From this it is evident, that though the permanent gases and the atmosphere do not sensibly conduct caloric, yet, in common with liquids and other transparent bodies, they permit its passage without being themselves appreciably affected by it. All the caloric received by the earth from the sun—the amount of which, to each acre in the latitude of London, is calculated by FARADAY to be equivalent to that which is generated by the combustion of sixty sacks of coal—thus travels through the intermediate space of ninety-five millions of miles, without sensibly affecting the temperature of the atmosphere, or that of the subtle medium beyond it. When heat emanates from any body in this way, it is said to be radiated from it, and the imponderable itself is denominated *radiant heat*. Thus, if a bar of heated metal be suspended in a room for some time, the excess of caloric contained in it will pass off in all directions, and the metal ultimately indicates only the same temperature as the surrounding objects. During the cooling, the heat passes off at all points of the body in direct lines as from a centre—hence the term *radiated.* To prove that convection and radiation are distinct processes, and that the latter is not a consequence of the former, all that is necessary is to expose a heated body in the vacuum of an air-pump, in which case it will be observed that the emission of caloric is much quicker even than if it were allowed to cool in contact with the air.

In simple language, the rate of cooling expresses the radiating power; and Leslie ascertained that the radiating power of bodies was more influenced by the state of their surface than by the nature of the material. A bright tin globe filled with water at a certain temperature was allowed to cool, and the time being carefully noted, it was found that the contents of the vessel cooled half way to the temperature of the room, in one hundred and fifty-six minutes. When the same experiment was repeated with the surface of the globe coated with lamp-black, it was observed that the mercury in the thermometer fell through the same space as it did in the first experiment in eighty-one minutes: thus showing, that by the alteration of the surface the radiating power was doubled. Count Rumford corroborated this observation by another experiment. Taking two brass cylinders of equal size and capacity, and investing one of them tightly with linen, while the other was left bare, he filled the two with boiling water, and allowed them to cool. During this process, he observed that the coated cylinder lost 10° of its original temperature in thirty-six minutes and a half, while the other required fifty-five minutes to pass through an equal range. Hence may be deduced the important practical inference, that liquids are best kept warm in highly polished vessels, and that it is an error to wrap them round with cloths or other coverings, which radiate the heat more rapidly than polished metals.

By following the method of Leslie and Count Rumford in the foregoing experiments, namely, coating the heated surface with various materials, and observing the time required in cooling, or, as will be presently noticed, by concentrating the rays radiated from a certain extent of surface, and ascertaining their intensity by their action upon a delicate thermometer, the comparative radiating power of different bodies may be ascertained. By this method it has been found that lamp-black is superior in radiating power to any other substance hitherto submitted to experiment, and that if this be represented by 100

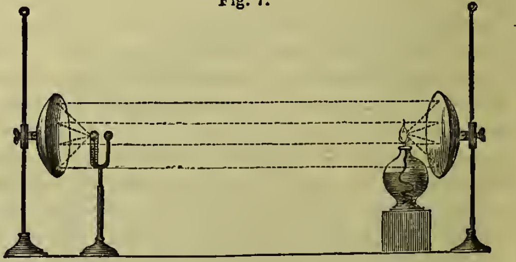
Writing paper will be	98
Resin,	96
Sealing wax,	95
Crown glass,	90
Indian ink,	88
Ice,	85
Isinglass and red lead,	80
Plumbago,	75
Tarnished lead,	45
Polished lead,	19
" tin plate, gold, silver, copper,	12

From this table it will be seen that lamp-black irradiates five times as much of the caloric of boiling water as clean lead, and eight times more than bright tin. The general low radiating power of the metals is increased if these be allowed to tarnish, as exhibited in the case of lead in the preceding table. Smoothness of surface, however, does not always act in relation to other bodies as it does in metals, for glass and porcelain, although their surface is smooth, always radiate very powerfully. When the actual radiating surface is metallic, it is not affected in a sensible manner by the substance under it; thus glass, coated with gold leaf or tinfoil, possesses the radiating power of the superimposed metals.

In general, the rapidity of cooling of any body depends upon the excess of its temperature over that of the external air; the hotter it is, the more freely does it give out caloric in a given time, and, as its temperature sinks, the longer is it in parting with the excess. Dulong and Petit found that the rate of cooling differs according to the nature of the atmosphere surrounding the heated bodies; they also observed, whilst making experiments upon bodies in vacuo, that if they acquired heat in an arithmetical ratio, the same would be radiated in a geometrical one.

Radiant heat is absorbed, reflected, or transmitted, according to the nature of the body on which it impinges; and the absorption, reflection, or transmission is in every case governed by peculiar laws. Polished metallic surfaces reflect the greater portion of the heat which falls upon them; and the incidental and reflected rays are in the same plane, and make equal angles with the reflecting surface. If two concave metallic mirrors be placed directly opposite to each other at some distance, and a lighted candle be fixed in the focus of one of them, the rays of heat received by the latter will be found reflected to the opposite mirror, where, instead of being absorbed, they will be further reflected and concentrated in the focus of this one; and, if a delicate differential thermometer be placed at this point, the quantity of heat thus concentrated may be registered. Such was the method adopted by Leslie, Melloni, and others, in their researches upon heat, as shown in the annexed engraving, Fig. 7. In this case the reflectors, if thoroughly polished, do not acquire a perceptible increase of temperature, nor indeed do any of those bodies which throw off by reflection the rays of heat incident upon them. It is only when the reflection is incomplete, either from the nature of the body or the want of a sufficient polish, that heating of the mirrors takes place. If in the above experiment a reflector of glass were

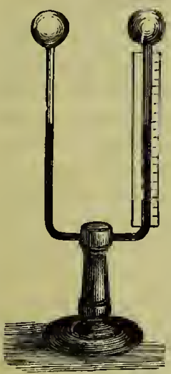
Fig. 7.



used instead of one of metal, only a very small portion of the calorific rays would be reflected, the greater part being absorbed by the disk, which in consequence would readily indicate a higher temperature; but by coating the surface of the glass with gold leaf or bright tinfoil, it will then became a polished metallic mirror, capable of powerfully reflecting the calorific rays. By experiments such as these, **Leslie** demonstrated that the reflecting power of a body is chiefly dependent on the nature and condition of its surface, and that those qualities which are adverse to radiation are such as promote reflection. Bright smooth metallic surfaces, such as polished silver, brass, or steel, which are strongly retentive of their own heat, are little prone to receive it from other sources, but cause its reflection in the same plane, and at an angle equal to that at which it strikes the surface. It is to this circumstance that the Dutch oven and meat screen owe their great efficacy in culinary processes.

The *differential thermometer* or *thermoscope*, to which allusion has been made in the preceding passage, and which is represented in the last figure in the focus of the left-hand reflector, is shown on a larger scale in Fig. 8, and consists of two bulbs, A and B, containing air, united by a tube twice bent at right angles, in which there is a little colored sulphuric acid. This is essentially an air thermometer, from which the atmospheric pressure is excluded. When heat is applied to one of the bulbs, the air within it expands, and draws the fluid towards the other, when either its depression or elevation, showing the amount of the expansion, may be read off on the scale. It is evident that this instrument cannot be employed to indicate general changes of temperature in the surrounding medium. It is not affected by such changes, which act equally on both bulbs; but when one of these is exposed to any source of heat which does not affect the other, as when it is placed in the focus of a reflector, the *difference* of temperature between the two bulbs is immediately and very sensibly indicated by the recession of the fluid from the heated towards the cold bulb. The *thermopile*, an instrument still more sensitive to slight changes of temperature, will be described immediately.

Fig. 8.



Melloni performed a number of experiments with the view of ascertaining the comparative absorbent power of certain bodies for caloric. He employed a variety of heat sources of different degrees of intensity, and fixed the ball of a thermoscope coated with lamp-black at such a distance from each, that the liquid contained in it recorded the same degree of temperature in every instance. The distance being marked, the ball was removed and coated with other substances instead of lamp-black, and then successively exposed as before to the action of the heat radiated from different sources. The results showed a remarkable variation, according to the source of the caloric. Thus, when the ball was coated with white-lead and exposed to the rays from the flame of an oil lamp, it indicated only 53; but when red-hot platinum wire was substituted for the flame of the lamp, it was found to be 56; with a copper plate, it indicated 89; and, when exposed to a canister of boiling water, it registered 100. In each of the preceding cases, however, the thermoscope when blackened exhibited 100. The subjoined tabulated results, showing the relative absorbability of different kinds of heat, were obtained in this manner:—

Thermoscope coated with	Naked flame from oil lamp.	Incandescent platinum.	Copper at 750°.	Canister of water at 212°.
Lamp-black, ...	100	100	100	100
White-lead, ...	53	56	89	100
Isinglass, ...	52	54	84	91
Indian ink, ...	96	95	87	85
Shell-lac, ...	43	47	70	72
Polished metal,	14	13·5	13	13

With regard to the heating of bodies by radiation, **Knoblauch** has shown that the effect produced when the radiated heat is *intensified* is totally independent of the temperature of the source, and is determined only by the nature of the absorbing bodies, which receive certain rays more readily than others. This was proved by coating one side of a sheet of metal with lamp-black, one half of the reverse being covered with carmine, and the other with black paper, and exposing the latter alternately to the action of an argand lamp, and a metal cylinder raised to 212°, while the side covered with lamp-black was turned towards the thermopile. With this arrangement the following results were obtained:—

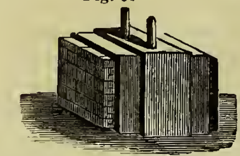
Sources of heat.	Direct radiation.	Interposed Carmine.	Black paper.
Argand lamp, ...	35	9·50	10·75
" "	50	13·75	15·25
Cylinder heated to 212°, ...	35	10·87	10·12
" "	50	15.62	14·00

To determine how far the thickness of bodies affected their heating by radiation, he used a metal plate coated with layers of varnish:—

Sources of Heat.	Direct Radiation.	METALLIC PLATE										
		Naked.	Covered with									
			Layers of Varnish.				Layers of Black Lac.				Layers White Lead.	
			1.	2.	4.	8.	Thin.	Thick.	Thicker.	Thickest.	Thin.	Thick.
Argand lamp, ...	35°	6·50°	8·25°	8·25°	8·25°	8·25°	7·12°	8·25°	8·62°	9· 5°	7·25°	8·00°
" "	60°	10·50°	14·50°	15·12°	15·62°	15·75°	14·50°	16·25°	17·37°	18·12°	16·12°	18·50°
Metal cylinder heated to 212°,	35°	6·50°	9·00°	9·25°	9·50°	9·50°	9·12°	9·87°	11·62°	12·00°	8·75°	9·62°
" "	60°	10·50°	17·50°	17·50°	20·12°	20·75°	18·62°	20·25°	21·37°	20·17°	17·00°	19·50°

From these results it appears that the substances employed are more strongly heated in proportion as their thickness is greater, within certain limits. MELLONI and LESLIE arrived at a different conclusion, in consequence of having used plates of such thickness that only a small proportion of the heat absorbed could penetrate to the side which was turned towards the thermoscope; KNOBLAUCH, on the contrary, employed media, the thickness of which was not too great to allow each successive layer to be heated, and thus to act upon the metallic surface.

Fig. 9.



The Thermopile.—MELLONI found that caloric was transmitted by many bodies which were impervious to light, and these he termed *diathermous* or *heat-transmitting*, in contradistinction to *diaphanous* or *transparent* bodies. In conducting his experiments on this subject, he employed, in connection with a very delicate galvanometer, an instrument which he termed a thermopile. This consisted of a number of pairs of bars of bismuth and antimony joined together, and so enclosed in a cylinder—see Fig. 9—that by turning one end of the latter towards the region whence the heat is radiated, it would fall upon the alternate points of junction of the bars of metal, and excite, as is well known, a current of electricity, the intensity of which is in proportion to the amount of heat received. By wires connecting both ends, *x* and *y*, of this battery with the galvanometer, the electricity was measured; and thus was obtained a ready and delicate method of estimating the amount of heat transmitted. Fig. 10 shows this arrangement, in which the pile is introduced. Both ends of the bars are blackened with soot, in order that the absorption of the rays of heat falling on them may be the more complete. By means of screens, *a* and *b*, the pile is preserved from the effects of currents of air; *b* has a conical shape, and is intended to concentrate the rays of heat when very feeble on the end of the pile. The pile is firmly bound, as represented at *p*, and fixed to a sliding stand in a perfectly horizontal position. *x* and *y* are bars in connection with the opposite ends of those of the pile, to which the wires *g* and *h* are screwed at one end, the other being in connection with the helice of coated wire that serves to act upon the galvanometer at *m* and *n*. The galvanometer is composed of a carefully selected and well magnetized pair of needles, bound together with fine copper wire, as seen in Fig. 11, and freely suspended in the middle of a glass cylinder, C, by a single fibre of silk which is attached to a ball, *f*, by turning which the needle may be raised or lowered at will. The helice, or multiplicator, in the midst of which the needles are suspended, is constructed by winding coated copper wire round a metal frame in forty layers, and properly isolated. Both the cylinder and multiplier are fixed to a table, so that when the needle hangs freely from *f*, it will rest in the centre of the closely divided circle, pointing to zero in the plane of the magnetic meridian. When the pile and multiplier are connected, the least change of temperature that may

Fig. 11.

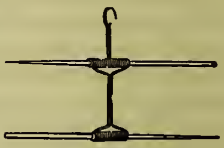
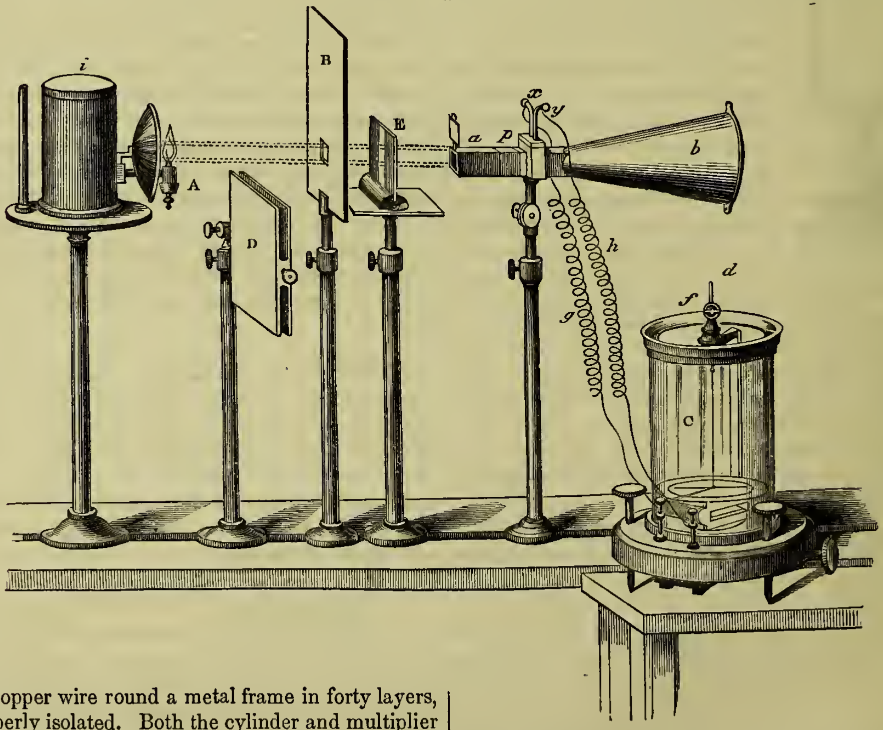


Fig. 10.



affect the ends of the compound metals deflects the needle, and the amount of this deflection may be noted on the divided circle. When working with this instrument, the first deviation of the needle must be carefully distinguished from the proper angle of deflection—*id est*, from the angle which it makes with the magnetic meridian, when unaffected by any electrical currents. If the equilibrium of the galvanometer is disturbed by a stream of electricity, it returns from the point to which it has been deflected, with a certain degree of velocity, which causes it to go beyond zero; it will oscillate thus for some time before the stationary line is attained. To avoid the delay which these oscillations would occasion, Melloni ascertained by experiments the ratio between the first and final deflection—*id est*, he determined how large the final deflection is that corresponds to the original one. The knowledge of this relation offers great advantages, inasmuch as each experiment lasts only ten or twelve seconds, whereas, if the operator had to wait till the needle became stationary, several minutes would be required.

If the principle of the apparatus comes to be considered, it will be evident that the relation which exists between the difference of temperature of the soldering points of the pile and the deflection of the needle cannot be ascertained in an absolute manner. To give the deflection a definite value as to the amount of caloric, Melloni had to determine—after establishing the fact, that the strength of the electric stream from a pile of bismuth and antimony is proportional to the difference of temperature of the soldering points—the relation of the deviation of the needle to the strength of the stream. For this purpose, he placed at either end of the pile a constant source of heat—such as a Locatelli's lamp—at such a distance, that when working alone at one end it caused a deflection of about 40° to the right, and, when placed at the other, the deflection marked 35° to the left side; but, when the sources of heat were permitted to operate on both ends at once, the deflection to the right marked 15°. From this behavior it was inferred that the difference between 40° and 35° corresponded with 15° counted from 0°. By operating in this way, it may easily be understood how, by changing these experiments, a table may be constructed, the first column of which expresses the observed deflection, and the second the corresponding number of degrees which would be arrived at if the deviation were proportional to the strength of the stream, and the action of the latter on the needle were not the weaker the more the latter is deflected. With the apparatus employed by Melloni, the numbers on both columns up to 20° were equal—that is to say, till 20° the deflection of the needle is proportioned to the strength of the stream; but with the observed deflection, 25, 30, 35, 40, and 45°, correspond the value 27, 35, 47, 62, and 83° of the second column. A stream, therefore, that produces a deviation of 40° is 62 times stronger than another that causes only a variation of one degree. Melloni so arranged his experiments that the deflections were always less than 30°.

To return to the manner of working the apparatus: if the body emitting rays of heat be fixed in the focus of a reflector that impels the rays of heat in a horizontal line with the pile, and one of the ends of the latter be exposed to them, the effect upon the needle will, upon the principles already laid down, be indicative of the quantity of radiated heat. When different sources of caloric are thus presented in succession, the register of the deflection of the galvanometer will show the difference of radiation.

Fig. 12.

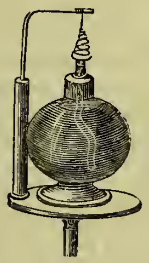


Fig. 13.

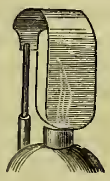
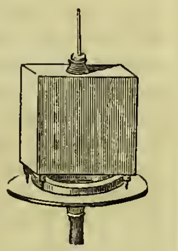


Fig. 14.



Transmission of Heat through Thin Plates.—The bodies employed by Melloni were a Locatelli's lamp, fixed as at A in Fig. 10; a coil of platinum kept at incandescence by the flame of alcohol, as seen in Fig. 12; a blackened copper foil fixed to a stand, and heated with a spirit lamp to 752°, as represented in Fig. 13; and a brass canister filled with water kept at 212°, as shown in Fig. 14. One or other of these was placed on a movable support, as at A, behind the perforated screen, B, the rays being concentrated when necessary by the reflector at A, and received at a certain distance from this upon the thermoscope. The sensitiveness of the latter was proved by placing a double screen of polished copper, D, between it and the source of heat, so as to intercept all the calorific rays, and observing the deflection of the needle of the galvanometer in C, when the screen was removed. The elevation of temperature produced by the direct action of the radiating body being thus known, the substance to be examined was then introduced in the place of the screen, as at E. By observing the difference of temperature as indicated by the needle now, and comparing it with the effect produced without the screen, the proportion of heat transmitted by any interposed body was at once ascertained. By this method, Melloni found that plates of rock-salt of great transparency, and varying in thickness from one-twelfth of an inch to two or three inches, transmitted ninety-two out of every hundred rays of heat which fell upon them, no matter from what source derived. As the remainder of the rays were found to be reflected from both surfaces of the plate, it may hence be concluded that what the colorless plate of glass is to rays of light, the plate of rock-salt is to those of heat. Sometimes the calorific rays which pass through one body are intercepted by a plate of another body, or by another plate of the same. In experimenting upon this, Melloni found that the caloric which has passed through one plate of glass, becomes less subject to absorption in passing through a second and a third plate of the same material. Thus, of one thousand rays of heat from an oil lamp, four hundred and fifty-one were intercepted in passing through four plates of equal thickness, and—

Of these the first plate intercepted	381
" the second "	43
" the third "	18
" the fourth "	9
	451

It was found by Delaroche that the higher the temperature of the source of heat, the greater in proportion to the whole is the quantity which passes through a plate or screen of glass. He observed that from a body heated to 182° only one-fortieth of the whole permeated, whereas when the temperature was 346° the one-sixteenth passed through, and when the heat was raised to 960° Fahr. as much as one-fourth of the whole amount of heat was transmitted. To show the independence of diathermacy and translucency, Melloni took a blackened ball of copper heated to 400° Fahr., and placing it midway between the blackened bulbs of two thermoscopes so that they might receive an equal amount of heat, noted the effect; then fixing between the ball and the instruments for measuring the heat plates of rock-salt and glass of equal thickness, it was quickly observed that the temperature of the bulb behind the former was much more elevated than the other—thus showing that more heat passed through it than through the glass one, although in transparency they were equal. In liquids this independence is still more manifest. Thus, out of one hundred rays that fell from an argand lamp on each of four fluids equally transparent—namely, water, oil of turpentine, ether, and sulphuric acid—the number of rays of heat transmitted were :—

Water	11
Sulphuric acid	17
Ether	21
Oil of turpentine	31

The following is a tabulated statement of some of the results ascertained by Melloni on the subject of the transmission of heat through various bodies of equal thickness :—

Name of the interposed substance. Common thickness 0·102 inch.	Transmission of 100 rays of heat from			
	Naked oil flame.	Red-hot platinum.	Copper at 732° F.	Copper at 212° F.
Rock salt, transparent and colorless,	92	92	92	92
Sicilian sulphur, yellow,	74	77	60	54
Fluor spar, limpid,	72	69	42	33
Rock crystal, cloudy,	65	65	65	65
Beryl,	54	23	13	0
Flint glass,	67	—	—	—
Plate glass,	39	24	6	0
Iceland spar,	39	28	6	0
Rock crystal, limpid,	38	28	6	0
" brownish,	37	28	6	0
Tourmaline, dark green,	18	6	3	0
Citric acid,	11	2	0	0
Alum,	9	2	0	0
Sugar candy, colorless,	8	1	0	0
Fluor spar,	8	6	4	3
Ice, transparent and colorless,	6	0	0	0

Similar experiments being performed with liquids contained in glass, the stratum being 0·362 inch in thickness, and the source of heat being in each case flame from an argand oil-lamp, the annexed results were obtained :—

Bisulphide of carbon,	63
Bichloride of sulphur, red-brown,	63
Terchloride of phosphorus,	62
Essence of turpentine,	31
Colza oil, yellowish,	30
Olive oil, greenish,	30
Ether,	21
Sulphuric acid, colorless,	17
" brown,	17
Nitric acid,	15
Alcohol,	15
Distilled water,	11

The fact that bodies which are pervious to light do not maintain the same relation to heat, is best exemplified by sulphate of copper, which permits the passage of blue light abundantly, but absolutely intercepts caloric. On the contrary, the opaque glass which is used for polarizing mirrors, allows the thermal rays to pass, but quite intercepts the light; and smoked rock-salt and black mica act in a similar way. Radiated heat is not only transmitted, but refracted in the same manner as light. This is proved by the well-known property of convex lenses or *burning glasses*, which concentrate not only the light, but the rays of heat, in the focus. Caloric further resembles light in apparently consisting of rays which possess different degrees of refrangibility, as may be proved by subjecting a beam of light to the action of a transparent prism of rock-salt, and examining the spectrum so obtained by means of a delicate thermometer. In this case it will be found that the heat varies at different parts of the spectrum; and experiment has shown that when the rays of the sun are operated upon, the most part of the rays of heat are less refrangible than even the red light; the maximum temperature being found at some distance below the extreme red. The refrangibility of the rays varies with the source of heat; the higher the temperature the greater is the refraction. For example, the rays of heat emitted from an argand lamp are refracted all over the spectrum, but the maximum intensity is about the middle; from ignited platinum the maximum falls nearer to the red; from copper heated to 750°, nearer still; and so on till the temperature of the source cools to 212°, when it is found to emit scarcely any of the more refrangible rays.

Specific Heat.—Bodies have different capacities for heat; or, in other words, the application of the same amount of caloric will elevate the temperature of divers substances unequally. This capacity for caloric, varying in different bodies, is termed their *specific heat*. If a certain weight of water, at the ordinary temperature of the atmosphere, be mixed with an equal quantity of this liquid raised to a higher degree, the mixture will indicate a mean between these extremes; but if another liquid, such as oil or mercury, be added, instead of the second portion of water, a great difference will be observed. When a measure of water at 60° Fahr. is agitated with as much mercury at 140°, the compound, instead of marking 100° as in the preceding case, will indicate only 86·6°. Again, if mercury at 40° be added to an equal bulk of water at 156°, the heat of the latter is reduced by 3·7°, which, being absorbed by the fluid metal, raises it to 152·3°, so that each degree which the water indicates by the instrument has the effect of 30·35° upon the fluid metal. Taking, then, the capacity of water for heat to be unity, that of mercury will be found from the above results to be 0·033. The capacity of any other body for heat may be determined with tolerable accuracy in the same way; the sides of the vessel, however, are liable to radiate more or less caloric, and will, of course, cause a slight deviation from absolute accuracy in the results.

Many plans have been proposed for estimating the capacity of bodies for heat. The method just described was followed by **Wilke**, **Crawford**, **Kirwan**, **Dalton**, and others; whilst **Delaroche**, **Berard**, **Neumann**, and **Regnault** proceeded on the principle of allowing equal weights of bodies to be exposed to the same cooling medium, and observing the difference in the time which they required to fall to the same degree; or, inversely, the time was noted which the bodies, when subjected to the same temperature, required to arrive at the marked degree. The difference, of course, depended upon the capacity for caloric, and from this datum the latter was relatively estimated. **Lavoisier** and **Laplace** endeavored to arrive at more correct data, by ascertaining how much ice the body dissolved in cooling down to the freezing point; but this method was likewise liable to error, for the ice retains a portion of water which has been liquefied, and, therefore, the measurement of the quantity dissolved cannot afford a perfectly correct estimate; besides, portions of what has been rendered fluid are liable to be frozen again, and in either case the results must be incorrect. **Dulong** and **Petit** conducted their researches by allowing spheres of equal size, equally heated, to cool, and noting the time which they required to fall to a given point; this, of course, will depend on the relative amount of heat which they contain, provided the radiation is rendered equal. The capacity of bodies for caloric is expressed by *relative* and *specific* heat: the former is generally applied when the determination is made as regards the volume, and the latter when it has reference to the weight of the substances.

The following table shows the specific heat of the substances mentioned, between 32° and 212° Fahr. :—

Name.	Specific heat; water = 1.		Authority.
Arsenic, ...	0·0814	....	Regnault.
Antimony, ...	0·0508	....	,,
Animal charcoal, ...	0·2608	....	,,
Charcoal strongly ignited, ..	0·2415	....	,,
,, moderately heated,	0·2964	....	De la Rive and Marcet.
Bismuth, ...	0·0308	....	Regnault.
Bromine, ...	5·1350	....	De la Rive and Marcet.
Cadmium, ...	0·0567	....	Regnault.
Copper, ...	0·0951	....	,,
Cobalt, ...	0·1069	....	,,
Coke—from gas retorts, ...	0·2023	....	,,
,, Anthracite, containing 3 per cent. of ash,	0·2017	....	,,
,, from Cannel coal, containing 4 to 5 per cent. of ash, ...	0·2031	....	,,
Diamond, ...	0·1469	....	,,
Glass, ...	0·1976	....	,,
Gold, ...	0·3241	....	,,
Graphite, natural, ...	0·2019	....	Regnault.
Graphite, artificial, ...	0·1970	....	,,
Iodine, ...	0.0541	....	,,
Iron, ...	0·1137	....	,,
Ice, ...	0·5130	....	,,
Iridium, ...	0·0368	....	,,
Lead, ...	0·0314	....	,,
Manganesium, containing carbon, ...	0·1414	....	,,
Mercury, ...	0·0333	....	,,
Molybdenum, ...	0·0722	....	,,
Nickel, ...	0·1086	....	,,
Palladium, ...	0·0593	....	,,
Platinum, ...	0.0324	....	,,
Phosphorus, ...	0·1887	....	,,
Selenium, ...	0·0837	....	,,
Sulphur, ...	0·2026	....	,,
Silver, ...	0·0570	....	,,
Tellurium, ...	0·0515	....	,,
Tin, ...	0·0562	....	,,
Tungsten, ...	0·0364	....	,,
Uranium, ...	0.0619	....	,,
Zinc, ...	0·0955	....	,,

The specific heat of bodies varies with their state of expansion, or, in other words, with any alteration in the distance of their particles from each other. Mechanical compression, sufficient to produce a permanent alteration in density, is attended by a corresponding decrease in specific heat. **Regnault** found the capacity for heat of a piece of soft copper to be, in two experiments, from 0·09501 to 0·09455; but after subjecting it to an atomical disarrangement by hammering, the specific heat diminished, and became 0·0936 to 0·0933. When, however, the original state of the bar was restored by annealing, an increase was experienced, and two trials gave respectively 0·09493 and 0·9479. As with solids, so also is it with liquid and aeriform bodies. When these are compressed much heat is liberated; indeed, with aeriform bodies, the heat disengaged is so abundant as to be capable of igniting tinder and other inflammable materials.

The reverse takes place when gaseous bodies are allowed to expand, by withdrawing the pressure; and in proportion as the rarefaction is greater, so also is the capacity for heat of the expansive fluid augmented.

A beautiful example of this law exists in the atmosphere. It is well known from the observations of aeronauts, and those who have ascended high mountains, that the temperature of the air decreases in proportion as the region is elevated, and that this diminution borders closely upon 1° Fahr. for every three hundred feet. Even in tropical climes some of the mountains are perpetually capped with snow, at a definite altitude, subject only to some little variation arising from the nature and distribution of the land beneath. The cause of this cold is the attenuation of the air as it extends from the earth into space, by which its capacity for heat is so greatly increased that a far more elevated temperature would be required to maintain it at the same warmth as the atmosphere near the surface of the ground. The appended table, from **Daniell**, gives the approximate distribution of heat by the dilatation of the atmosphere at the equator and poles, supposing the normal temperature at both these places to be respectively 80° at the former and 0° Fahr. at the latter:—

Altitude in feet	Temperature at the Equator.	Temperature at the Poles.
0	80	0°
5000	64.4	— 18·5
1·0000	48·4	— 37·8
1·5000	31·4	— 58·8
2·0000	12·8	— 82·1
2·5000	— 7·6	— 109·1
3·0000	— 30·7	— 140·3

Taking the limit of the atmosphere to be forty-five miles high, it is probable that the most subtle and permanent gases would not only be condensed but even solidified by the degree of cold which would there act upon them, could the ordinary pressure on the surface of the globe be sustained.

Elevation of temperature also increases the capacity of bodies for caloric, and hence it requires the application of a greater heat to raise their temperature when they have combined with a large amount of caloric than in the contrary case. The appended table shows the increasing capacity of the bodies enumerated within the limits assigned:—

Name.	Capacity for heat between 32° and 212°.	Ditto between 32° and 572°.
Mercury,	0·0330	0·0350
Platinum,	·0335	·0355
Antimony,	·0507	·0549
Silver,	·0557	·0611
Zinc,	·0927	·1015
Copper,	·0949	·1013
Iron,	·1098	·1218
Glass,	·1770	·1900

Water ranks first of all bodies yet known in its increasing capacity for heat, at an elevated temperature. Between 22° and 32° Fahr. the specific heat of solidified water is 0·505, assuming it to be unity in the liquid state, and if converted into steam the specific heat of the vapor increases with its state of dilatation. This property contributes in no small degree towards moderating the rapidity of the transitions from heat to cold, and *vice versa*, in the atmosphere, owing to the large quantity of heat which is absorbed by or emitted from the water of the ocean, when the temperature exceeds or falls short of the normal range.

In the determination of the specific heat of vapors, much remains to be done, to arrive at satisfactory results.

Dulong and Petit endeavored to establish the relation of the specific heat of bodies and their atomic equivalent. This relation they expressed by a general law, that the specific heats of elementary bodies vary inversely with their atomic weights; and that an atom of any one simple substance, whether small or large, has the same capacity for caloric, and requires the same quantity of this imponderable to raise its temperature through a given number of degrees, as an atom of any other element. Regnault, by observing that the product of the specific heat into the atomic weight is nearly a constant quantity, represented by 3·2°, advanced a considerable step towards establishing the existence of this general law; still, there are many exceptions which have not yet been reconciled with it.

Latent Caloric, or Heat of Fluidity.—Black asserted, many years ago, that fluidity was owing to the chemical combination of matter with a certain amount of heat, which could not be detected by the thermometer. To this he applied the term *heat of fluidity*, or *latent heat*, assuming that heat, by its chemical combination with matter, counteracted the cohesive attraction of the atoms of solids, and thus explaining the phenomenon of liquefaction, as that condition in which the cohesive and repellent forces are in exact equilibrium. This view of the subject appears to be well founded; and it is believed that the condition in which matter is found, as solid, liquid, or aeriform, entirely depends on the amount of caloric in combination with it. This has been proved with reference to most substances, and there is strong ground to believe that even the most refractory may be converted into an elastic vapor, and the most permanent of the latter class rendered solid, by the communication of heat on the one hand, and its abstraction on the other.

Solids very much vary in the phenomena which attend their conversion to fluidity; while many of them are transmuted at once to this state, others pass through various stages of softness previous to their assuming it. The following table expresses the melting or solidifying point of a few bodies:—

	Deg. Fahr.
Lead melts at	612
Bismuth,	476
Tin,	442
Sulphur,	232
Wax,	142
Spermaceti,	112
Phosphorus,	108
Tallow,	92
Oil of Anise,	50
Olive oil,	36
Ice,	32
Milk,	30
Wines,	20
Oil of turpentine,	14
Mercury,	—39
Liquid ammonia,	—46
Ether,	—46

It must be remarked, however, with regard to the above table, that when the preceding substances in a melted state are cooled down, they do not solidify as soon as the foregoing temperatures have been attained. A further quantity of caloric must be abstracted before they assume the solid form; and, under some circumstances, this abstraction of caloric may actually be indicated by a depression of the sensible temperature extending to several degrees before any change occurs. Thus, water, which, in the form of ice, always melts exactly at 32°, may be cooled down to 8°, or even to 5°, without altering its state of aggregation. To produce this curious effect, it is necessary that no solid substance be introduced into the water, and that it be kept perfectly still; for, should the least movement of the liquid be occasioned, it would immediately begin to solidify, and the mass would rise to 32°. The sudden rise of temperature is occasioned by the evolution of the caloric which was required to liquefy the mass, and, consequently, had remained insensible to the instruments usually employed for its detection. This caloric is generally called *latent heat;* but the same term is applied to that which is contained in solid bodies, as well as to the heat of fluidity.

Much caloric is always absorbed and becomes latent by the solution of solid bodies in various menstrua, and the degree of cold which this occasions is often very great. For philosophical, and often for industrial purposes, the method followed to effect a reduction of the temperature is, to dissolve various mixtures of salts in water or spirit, and the amount of heat which is required for their solution or their reduction to the fluid state, being abstracted from these liquids, and rendered latent, is sufficient to reduce the temperature of the whole mass to a greater or less extent. The following table expresses the proportions of various substances best adapted for producing cold:—

FRIGORIFIC MIXTURES WITH SNOW.

Mixtures.	Parts by weight.		Therm sinks—deg.	Degrees of cold.
Chloride of sodium,	1	From any temperature	to — 5	—
Snow,	2			
Chloride of sodium,	2		to — 12	—
Chloride of ammonium,	1			
Snow,	5			
Chloride of sodium,	10		to — 18	—
Chloride of ammonium,	5			
Nitrate of potassa,	5			
Snow,	24			
Chloride of sodium,	5		to — 25	—
Nitrate of ammonia,	5			
Snow,	12			
Strong sulphuric acid,	1		from + 32 to — 23	55
Water,	1			
Snow,	3			
Concentrated hydrochloric acid,	5		from + 32 to — 27	59
Snow,	8			
Concentrated nitric acid,	4		from + 32 to — 30	62
Snow,	7			
Chloride of calcium,	5		from + 32 to — 40	72
Snow,	4			
Crystallized chloride of calcium,	3		from + 32 to — 50	82
Snow,	2			
Fused potassa,	4		from + 32 to — 51	83
Snow,	3			

In making the foregoing mixtures, if snow be not at hand, pounded ice may be employed with equal effect.

When mixtures of salts and water are taken, the reduction is not so great; yet, when the compounds are finely powdered, and the solution rapidly effected, the cold produced is very intense:—

Mixtures.	Parts by weight.	Temp. falls—deg.	Degrees of cold.
Chloride of ammonium,	5	from + 50 to + 10	40
Nitrate of potassa,	5		
Water,	16		
Chloride of ammonium,	5	from + 50 to + 4	46
Nitrate of potassa,	5		
Sulphate of soda,	8		
Water,	16		
Nitrate of ammonia,	1	from + 50 to + 4	46
Water,	1		
Nitrate of ammonia,	1	from + 50 to — 7	57
Carbonate of soda,	1		
Water,	1		
Sulphate of soda,	3	from + 50 to — 3	53
Dilute nitric acid,	2		
Sulphate of soda,	6	from + 50 to — 10	60
Chloride of ammonium,	4		
Nitrate of potassa,	2		
Dilute nitrous acid,	4		
Sulphate of soda,	6	from + 50 to — 14	64
Nitrate of ammonia,	5		
Dilute nitric acid,	4		
Phosphate of soda,	9	from + 50 to — 12	62
Dilute nitric acid,	4		
Phosphate of soda,	9	from + 50 to — 21	71
Nitrate of ammonia,	6		
Dilute nitric acid,	4		
Sulphate of soda,	8	from + 50 to 0	50
Hydrochloric acid,	5		
Sulphate of soda,	5	from + 50 to + 3	47
Dilute sulphuric acid,	4		

The acids should be prepared by adding two parts by weight of the fuming nitric acid to one of water, and allowing the mixture to cool. When working with sulphuric acid, equal weights of strong acid and water are taken, and used after cooling.

A still more intense degree of cold may be attained by the rapid evaporation of liquids, such as bisulphide of carbon, ether, protoxide of nitrogen, and solid carbonic acid gas. By employing a bath of carbonic acid and ether *in vacuo*, Faraday reduced the temperature

166° Fahr. below zero; and Natterer, by means of bisulphide of carbon and protoxide of nitrogen, brought the thermometer to — 220°. The cause which operates in the case of the solution of solids in snow and water, or acids, is the same that induces the frigorific effect by rapid evaporation; but as the caloric which is rendered insensible or latent in the conversion of a liquid body to a gaseous state, is much greater than is necessary to convert a solid to the liquid form, hence it results that the depression of temperature produced by a rapid evaporation can be carried further.

Latent heat, the amount of which differs in different bodies, serves very important offices in the economy of nature, as well as in the chemical manufactures. When the temperature of the atmosphere in winter rises to 32°, masses of ice and vast accumulations of snow would suddenly liquefy, producing destructive inundations, were it not that in melting they must further absorb the heat of fluidity, which becomes latent, and thus the change is retarded and rendered gradual. In the manufactures, the importance of latent heat is illustrated by the employment of steam as the heating agent in numerous processes of distillation, evaporation, and carbonization; but the manner in which it acts in these cases will be better understood after some further explanation of the effect of heat upon liquids.

It has been shown that the change from the solid to the liquid form is the result of the combination of a certain amount of caloric with the substance, and that the heat so united becomes insensible to the thermometer, however delicate its construction. Instances of the absorption and disappearance of heat have been given in the melting of ice, metals, and other substances, capable of passing into the liquid state. In the fusion of metals, the temperature of the bath does not increase a fraction of a degree above the melting point, till the whole has undergone liquefaction, notwithstanding that heat has been pouring into the mass without intermission. The reason of this is, that as long as any of the metal remains solid, it abstracts all the excess with which the liquid may be charged, and combines with it to form more fluid. After the latter stage has been attained, if the temperature be still increased, the bath will continue to indicate a rising temperature till it acquires that degree at which the repulsive force of the caloric will have so far overcome the cohesion of the particles, as to expand them to such an extent that their gravity will be less than that of the air, bulk for bulk. The liquid will then be gradually transformed into vapor, and will manifest the phenomenon of ebullition, which is simply the commotion produced by the evolution of bubbles of the substance itself converted to the gaseous state, and which are generated by its union with the caloric supplied to the liquid. Whatever additional heat be now applied, the boiling fluid will continue to indicate the same temperature as long as any of it remains; and during the process, the vapor which escapes possesses *apparently* only the same amount of caloric as the liquid from which it is produced, but *actually* a greater amount in the shape of the additional *latent heat* by which it is converted into vapor.

These changes are more familiarly known as happening with water than with metals, for although the latter are frequently fused, they are seldom converted into vapor. During the melting of ice by the application of heat, the ice, or mixture of ice, and water, remains at 32° till the whole is melted; it is evident, however, that the water at 32° must now contain more heat than when, in the state of ice it indicated the same temperature. If heat continue to be applied, the water gradually acquires a temperature of 212°, at which point, provided the atmosphere is at the usual standard barometric pressure, and the liquid be contained in an open iron or copper vessel, it remains stationary. It is now rapidly converted into vapor, but both the liquid and vapor are still at the temperature of 212° Fahr. A little consideration will show that the heat which continues to flow into the liquid, is expended in converting it into steam; for as no indication of an increase is manifest, it must be evident that the surplus is rendered insensible in the process of converting the water into vapor. The quantity of heat necessary to effect this is much larger than is required to reduce the body from the solid to the liquid state. To estimate the amount of caloric expended and rendered insensible or latent in both cases, let a pound of water at 212° be mixed with the same weight of water at 32°, and it will be found that the mixture will indicate a medium between these points—that is to say, the pound of water at 212° will lose 90°, and the pound of water at 32° will gain 90°; so that the mixture will indicate 122°. But now let a pound of water at 212° be mixed with a pound of snow or ice at 32°, and the mixture will indicate only 51° Fahr., showing that the water has lost 161°, while the snow or ice has gained *apparently* only 19°. It is evident that the difference between these figures, or 142°, must have been absorbed or become latent in converting the snow or ice into water.

Applying the same test to steam or vapor of water at 212°, it will be found that one pound of water, which has been converted into steam, is sufficient to reduce six pounds and a quarter of snow or ice to the liquid state, and to raise it to 51°, from which it may be deduced that steam contains 967° of latent or insensible heat. Lavoisier estimates the amount, in round numbers, at 1000°.

Ebullition and Evaporation.—During the ebullition of water in common metallic vessels at the ordinary pressure of the atmosphere, no amount of heat applied can elevate its temperature beyond 212°, provided the steam passes off freely; a fact which is well deserving of consideration in domestic economy. Many causes, however, tend to vary the boiling point of water and of liquids in general. If it be contained in smooth glass vessels, ebullition takes place at two or three degrees above the usual standard; hence, if a coil of wire be introduced into water contained in a smooth glass vessel, and near the point of ebullition, this process will commence immediately. All angular bodies, and more especially metals, introduced among the liquid, cause the boiling to take place even in glass vessels at 212°. The adhesion of the liquid to the sides of such vessels seems to be the cause of impeding the boiling, and sometimes of making it to pass into vapor suddenly; hence in distilling in the laboratory the custom of introducing bits of platinum wire into the retort to facilitate the conversion of the liquid into vapor; without this precaution there is often danger of the retort being broken, or of the liquid operated upon being thrown over into the receiver. At each evolution of vapor that is formed during ebullition under these circumstances, the temperature falls to 212°; but when it has escaped, the contents of the vessel remain quiet till the temperature rises as before. Many substances, such as shell-lac, when applied to the interior of the vessel, prevent ebullition taking place at the usual degree; but the experiments of Dormy have proved that atmospheric air mixed with liquids influences their boiling point more than anything else, except pressure. He showed that the air which is dissolved in water acquires an increased elasticity, and forms minute bubbles in the interior of the fluid into which the steam dilates and rises to the surface. By long-continued boiling the air is nearly expelled; and in the course of some experiments it was found that the temperature could be raised to 360° in an open vessel without the phenomenon of ebullition taking place; finally, however, the disengagement of vapor was so sudden that it caused a loud explosive report, and shattered the vessel in fragments.

From what has been said, it is evident that the boiling point of liquids is not fixed, but is dependent upon various causes. The greatest effect is produced by the varying pressure of the atmosphere, which on an average is about fifteen pounds for every square inch of surface at the level of the sea; but the weight of the air varies at different heights, and according as it happens to be surcharged with watery vapor or not; consequently, at different elevations the boiling point will be different, and even at the same level the pressure or density varies so much as to cause a difference of four degrees or more of Fahrenheit's scale. It is absolutely necessary, therefore, to observe the pressure of the atmosphere when fixing the boiling point of liquids on the thermometer, and to make the necessary corrections. This is done by noting the height at which the mercury in the barometer stands at the time, and making the requisite allowance for any difference between that and the normal height of 29·92 inches, as shown by the following table, which embraces the extreme indications of the barometer at common levels, with the boiling points of water corresponding to these and the intermediate indications:—

Barometer indication. Inches.	Water boils. Deg. Fahr.
27·74	208
28·29	209
28·84	210
29·41	211
29·92	212
30·6	213

It thus appears, that under a diminished pressure water seethes at a lower temperature, and the same happens with other liquids. Saussure found that, on the top of Mont Blanc, water boiled at 184° Fahr. In deep mines, on the contrary, it requires a much higher temperature than 212° to bring it to a state of ebullition. On this circumstance has been based the construction of an instrument for determining the heights of mountains by the boiling point of water or other liquids.

When the pressure is removed by artificial means, as by creating a vacuum, the boiling point of water may be lowered about 145° under the usual temperature at which ebullition takes place. This has been turned to advantage in several manufacturing processes, where an exposure to the temperature of boiling water, under ordinary circumstances, for a length of time, would be prejudicial and sometimes destructive to the substances under treatment. The pharmaceutist and sugar-refiner are especially benefited by the application of this important fact in their respective processes. By operating under a low pressure, produced by creating a partial vacuum, the former can readily inspissate his vegetal juices to any desired extent without injury; whereas, if the same were attempted in an open vessel under the common atmospheric pressure, most of the active principle would be destroyed. In like manner, if the saccharine liquid of the sugar boiler were to be concentrated to the same degree to which it is usually carried in an open pan or boiler, nearly the whole of the crystallizable sugar would, by an allotropic molecular arrangement, pass to an uncrystallizable sirup. By an increased pressure the converse of this happens, and water may be made to attain a temperature of 300°, 400°, or upwards, before ebullition. An instrument known as Papin's digester, which is simply a strong metallic vessel with a safety valve, is constructed on this principle, and is used to macerate bones and other substances in liquids raised to a higher temperature than that of boiling water.

Solid bodies dissolved in water or other liquids produce, to a certain extent, the same effect as high pressure; generally, the elevation of the boiling point varies according to the nature of the substance in solution, but it uniformly increases with the same body till the liquid is saturated. Tables founded upon this law have been drawn up, for the purpose of estimating the amount of saline matter in a liquid from its boiling point.

Ebullition consists mainly in the conversion of the liquid into vapor, and so far is synonymous with evaporation; which differs from it, however, inasmuch as the latter takes place at all temperatures—whereas a certain range of heat is required, under every circumstance, before the former phenomenon is observed. This may be proved by allowing a shallow vessel containing water to remain exposed for some time; upon examination it will be found that a portion will have disappeared—or, in other words, it will have evaporated to the extent of the loss. Most fluids are susceptible of this change, but those which boil at a low temperature are more volatile than others: thus alcohol is evaporated much quicker than water, and for the same reason ether is converted into vapor much more readily than even alcohol.

Evaporation is affected by the temperature and hygrometric state of the air, and the extent of surface exposed. It is evident that the latter must influence the rate of conversion into vapor, because this alteration can only take place at the surface: hence the amount of evaporation will be, *cæteris paribus*, in proportion to the superficies which the fluid presents. But when the air is surcharged with moisture, the change into vapor will be slow, even although the temperature be elevated, whereas, if it be dry, the fluid will disappear much quicker. In still air the evaporation is much slower than when a breeze or current of air is passing over the liquid; because, in the former case, the stratum of air immediately over the surface of the fluid becomes saturated and unable to take up any more moisture, whereas, when a current is established, a fresh and dry stratum is constantly presented to the liquid, and passes away loaded with vapour.

Evaporation, like ebullition, is greatly promoted by the removal of pressure; thus, by placing a cup containing ether or any other volatile fluid under the receiver of the air-pump and exhausting it, the fluid rapidly disappears, and an atmosphere of vapor is formed.

In all cases, however, where it is expedient that liquids should be quickly vaporized, heat is resorted to as the best and most ready agent. Heat, indeed, is the cause of evaporation at whatever degree or under whatever circumstances it takes place, just as it has been shown to be the cause of liquidity. Hence arises the important question, What is the least quantity of caloric required to effect the evaporation of a given quantity of liquid?—a question which bears on the economy of fuel in the generation of steam, and in many other manufacturing processes. Mr. Sharpe, of Manchester, arrived at the conclusion, that as the latent heat of vapor is increased with its degree of rarefaction, and as subtler vapor is obtained at low than at more elevated temperatures, there is no economy of caloric, and therefore no saving of fuel by evaporating or distilling liquids *in vacuo*. Watt further showed that the same weight of steam, whatever density it may possess, contains the same quantity of heat, its insensible or latent caloric being increased in proportion as its sensible is absorbed. Thus he found that a given weight of steam at 212°, and consequently possessing 180° of sensible heat above the freezing point, gave off 950° more when condensed by injecting upon it water at 32°, making, with the sensible heat, a total of 1130° above the point of freezing. Again, the same weight of steam at 250°, and therefore possessing 218° of sensible heat, gave out, on being liquefied at the same temperature, only 912° Fahr., which, with the sensible heat, amounted exactly to 1130° also. This he assumed, therefore, as the amount of caloric necessary to convert water at 32° into steam, either of a high or low tension; and hence, on this assumption, to ascertain the amount of latent or insensible heat in steam, at any temperature, all that is necessary is to deduct the sensible heat from 1130°, and the difference is the latent caloric.

These experiments appear to lead to the inference that, in the evaporation of liquids, generation of steam, distillation, *et cetera*, no material economy is gained by conducting these processes at low rather than at high temperatures; but the later and more carefully conducted researches of Regnault have shown that this assumption is not strictly correct, and although the difference does not lead to serious errors in practice, yet in reality the sum of the latent and sensible heat increases for each degree of Fahrenheit, by a constant quantity equal to 0·305°. This is illustrated in the annexed table, in which it is assumed that steam possesses no sensible heat below Fahrenheit's zero :—

LATENT AND SENSIBLE HEAT OF STEAM AT DIFFERENT TEMPERATURES :—

Pressure in atmospheres	Temperature.	Latent heat.	Sum of latent and sensible heat
0·044	0°	1114°	1114°
0·180	32	1091·7	1123·7
1·000	212	966·6	1178·6
8·000	339	877·3	1216·8

The increase here shown offers, however, but a small inducement to perform the processes already alluded to at low temperatures—so far as saving of fuel is concerned; while the increased amount of sensible heat which may be utilized advantageously when the steam is generated under pressure, renders it expedient that the latter mode of generating it should be resorted to. This is the case especially when steam is employed as a source of heat in the carbonization of ligneous matters, in the distillation of liquids, and, occasionally, in the concentration of saline and extractive solutions. The large amount of caloric which steam possesses renders it peculiarly adapted to such purposes; and hence, in all those manufactures where the products are of a salifiable or an extractive nature, steam is now generally employed to concentrate the liquors. In the culinary art, also, it is found to be much more eligible as a source of heat than the common method of exposing the apparatus directly to the action of fire. It is especially adapted for drying manufactured goods and for purposes of ventilation; in the one case, it is conveyed through cylinders over which the goods are conducted, and in the other through iron pipes, so disposed that the heat shall be given off in the most effectual way. In the latter case, experience has shown that the boiler should have one cubic foot capacity for every two thousand cubic feet of air to be heated to a temperature of 70° or 80° Fahr., and that the conducting pipe must present a superficies of one square foot for every two hundred cubic feet of space to be heated.

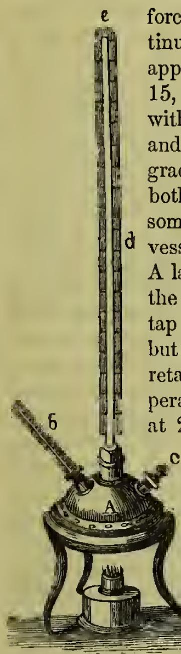
Elastic Force of Steam.—When different liquids are heated to their boiling points, they produce very unequal quantities of vapor. Water yields it in larger volume than any other known liquid. The following table shows the volume of vapor produced by a cubic inch of each of the liquids enumerated at their respective boiling points :—

Cubic inch.			Cubic inches.	
1	of water	expands to	1696	at the boiling point.
1	of alcohol	"	528	" " "
1	of ether	"	298	" " "
1	of turpentine	"	193	" " "

The great value of machinery at the present day in developing the resources of nations, and in fostering and extending commerce and internal intercourse, turns upon the expansive property of water under the influence of heat. This, as already stated, is such as to make it the most efficient motive power; and although it requires a higher temperature, and consequently a greater consumption of fuel, to generate vapor from it than many other liquids, yet its superior elasticity in the shape of steam is such as to render it preferable to any of them, even supposing they could be had as cheaply. When the vapor of water is heated alone, the rate of expansion is the same as that of air or any other elastic gaseous mixture when subjected to an equal temperature, and it may be confined in red-hot vessels without a great amount of elastic force being acquired. It is otherwise, however, if some water be contained in the vessel or cylinder, for then the generation of fresh vapor causes an addition of elastic force to that already exerted, so that in time the pressure on the walls of the vessel becomes irresistible.

Papin's digester, already mentioned, or an apparatus constructed on similar principles, is resorted to for determining the elastic force of steam when subjected to a continued increase of temperature. This apparatus, which is represented in Fig. 15, is a globular vessel, A, furnished with a thermometer, *b*, a stopcock, *c*, and a long glass tube, *d*, affixed to a graduated scale, *e;* the tube is open at both ends—the lower one dipping into some mercury in the bottom of the vessel, and on which the water floats. A lamp, placed under the globe, causes the water to boil, and so long as the tap is left open, this happens at 212°; but if the steam which is produced be retained by closing the tap, the temperature no longer remains stationary at 212°, but rises progressively as the steam is accumulated; and the mercury, which before marked only a height equivalent to thirty inches in the tube, now ascends till it reaches twice or thrice that elevation, according as the elastic force of the steam is increased.

Fig. 15.



Dulong and Arago have made some researches upon this subject, which are valuable, inasmuch as they throw considerable light upon the mechanical effect of steam. The results are, therefore, appended in the following table, from which it may be seen, that as the temperature rises, a given increment of heat produces a greater effect in augmenting the elastic force than at a lower temperature. If the atmospheric pressure, or the elasticity of steam at 212° Fahr., be taken as unity, the elastic force of steam at 240° Fahr. will be about one and a half, and at 250° Fahr. will be equal to two atmospheres. Thus an increase in the quantity of heat indicated by 38° Fahr. doubles the elastic force, and it also appears from the table that a further increase of 25° trebles the elastic force, and a further increase of only 18° quadruples it. Thus the elastic force evidently increases much more rapidly than the temperature. This circumstance has led to the introduction of high-pressure boilers as affording an increased motive power, with a less consumption of fuel, than when low-pressure boilers are used. The former have been found so advantageous, that, in mining and manufacturing districts, as well as for locomotives and steam vessels, high-pressure steam is now in general use:—

ELASTICITY OF STEAM AT HIGH TEMPERATURES.

Elasticity of steam, taking atmospheric pressure as 1.	Temperature Fahr.	Elasticity of steam, taking atmospheric air as 1.	Temperature Fahr.
1	212°·0	13	380°·66
1·5	239·96	14	386·94
2	250·52	15	392·86
2·5	263·84	16	398·48
3	275·18	17	403·82
3·5	285·08	18	408·92
4	293·72	19	413·78
4·5	300·28	20	418·46
5	307·5	21	422·96
5·5	314·24	22	427·28
6	320·36	23	431·42
6·5	326·26	24	435·56
7	331·70	25	439·34
7·5	336·86	30	457·16
8	341·78	35	472·73
9	350·78	40	486·59
10	358·88	45	491·14
11	366·85	50	510·60
12	374·00		

Combustion.—Allusion has already been made in the preceding pages to various sources of heat; but those which will fall to be considered in connection with the subject of this article, are certain material substances which, in the act of undergoing chemical changes, yield both heat and light. This process is termed combustion. At one period, and among the disciples of Lavoisier in particular, oxidation and combustion were considered synonymous. It is true, that in most cases of combustion, as in that of a common fire, the effect is produced by the oxidation of the materials; but cases of combustion occur when no oxygen is present. Antimony, for example, burns when heated in an atmosphere of chlorine; copper, or iron, when heated with sulphur; potassium, with cyanogen, *et cetera.* These instances demonstrate the fact that oxygen is not essential to combustion, although it is eminently capable of supporting it; and being so extensively disseminated in the atmosphere, it acts as the almost universal agent in this phenomenon.

Though the term *combustion* is generally limited to cases of chemical combination accompanied with heat and light, yet it is sometimes extended to express the union of bodies with oxygen effected at a low temperature. Iron, for example, when exposed to moist air, undergoes a change in oxidizing, whereby its metallic characteristics disappear; the constituents of the blood are modified by a similar chemical process, but in neither case is light produced; and if heat is generated in the former, it is quite inappreciable even by delicate instruments. In both cases, however, the effect produced is sometimes characterized as a process of *slow combustion.*

In cases of vivid, as distinguished from slow combustion, the heat and light seem to be evolved from the solid, liquid, or gaseous bodies which burn, and hence they are termed *combustibles*, while the gaseous atmosphere in which they are involved, such as oxygen or chlorine, is termed the *supporter of combustion*. It is evident, however, that this distinction is radically faulty, inasmuch as the phenomena of light and heat may be regarded as proceeding either from the one or the other. The combustible, usually so called, may be represented as supporting the combustion of the atmosphere in which it is enveloped, and the latter, regarded in this view, becomes the real combustible. In strictly philosophical language, the combustion proceeds from the combination, which can only take place at the point of contact; and therefore it is quite impossible to say to which of the bodies so combining is due the evolution of heat and light, or, in other words, which is the combustible and which the supporter of combustion.

Much difference of opinion exists as to the manner in which heat is produced, and the question is far from being solved at the present time. At one period it was thought that heat was a material constituent of the substance, which might be separated from it or combined with it like other substances. On this hypothesis all the gaseous bodies were regarded as compounds of the actual matter with the substance of heat and light, or *phlogiston*, as it was called; and when any one of these, such as oxygen, was made to unite with another body, and heat and light accompanied the combination, these phenomena were attributed to the evolution of phlogiston. Moreover, to account for the fact that some bodies, as metals, gained in weight by combustion, the phlogiston was supposed to be possessed of a principle of levity. LAVOISIER explained the evolution of caloric when certain bodies entered into combination, on the supposition that the specific heat of the substances before combustion was greater than that of the bodies produced, and that the difference was what was radiated or otherwise evolved from the burning body. Experiment, however, has shown that this theory is untenable, for in the case of the combustion of carbon, which is the commonest instance, the carbonic acid gas produced has a greater instead of a less specific heat than oxygen; and hence, in a case where caloric is actually given off, the result is found to be the very reverse of that which is implied in this explanation. More recently, THOMSON accounted for the effect on the assumption that every atom or molecule of simple bodies contains an equal amount of heat, and that, when a number of them combine, the caloric from one or more is expelled. But all these theories may be ranked as mere ingenious speculations. In the present state of knowledge, all that can be affirmed with certainty is the general principle, that heat is developed by chemical action.

Relative Value of different Combustibles.—The amount of caloric produced in the combustion of different bodies is variable, and the determination of the quantity so produced becomes a matter of the highest importance, as upon this depends the selection of particular substances for the production of heat economically. The course pursued in researches with this object in view is to burn a certain weight of the combustible, admitting for this purpose only the smallest possible quantity of oxygen or air, and so to conduct the heat through water that it shall be entirely absorbed by it. From the quantity of liquid raised through a certain range of temperature, the value of the combustible under experiment is estimated.

Proceeding upon this plan, and comparing a number of results, WELTER concluded that the heat eliminated depended upon the quantity of oxygen taken up, and that the amount developed by equal weights of oxygen, when made to unite chemically with other bodies, how different soever they might be, was always the same. In this opinion he was supported by the researches of other chemists. DESPRETZ, by uniting one pound of oxygen with any of the following substances, found that the water raised from 32° to 212° Fahr. was, with

Hydrogen, ...	29·5 pounds.
Charcoal, ...	29 "
Alcohol, ...	28 "
Ether, ...	28·5 "

Although the law laid down by WELTER appears to be confirmed by these results, yet there are several facts with which it does not accord. When iron is oxidized and the generated caloric is collected in water, the quantity heated by it from 32° to 212° is fifty-three pounds, or nearly double the weight which the same volume of the gas consumed with the substances above enumerated raises to the boiling point. Zinc, tin, and many other metals, similarly treated, produce effects which differ in like manner from the results tabulated by DESPRETZ. Even the same quantity of oxygen produces unequal effects with the same body, when it is capable of combining with it in various proportions Thus, when phosphorus is burned slowly, the amount of heat which it evolves in combining with one pound of oxygen is capable of heating only twenty-eight pounds of water to the boiling point; but when the combustion is conducted rapidly, so as to produce phosphoric instead of phosphorous acid, twice as much caloric is disengaged. Again, if charcoal be consumed with a limited supply of oxygen, so as to form carbonic oxide gas, and a quantity of this gas equivalent to one pound of carbon be ignited, it will be found that as much heat will be given off as will raise sixty-two pounds of water to the boiling point; whereas, if the carbon be ignited with its full complement of oxygen in the first instance, the heat obtained will be to the foregoing as 76·62, whilst the proportion of oxygen combined is as 2 to 1. From all these cases it appears that the quantity of heat developed by the combustion of a substance depends greatly upon the nature of the body itself. It cannot be denied, however, that the volume of oxygen which combines with the substance affords in most cases a pretty near approximation to the amount of heat developed in combustion; and hence the method in ordinary use for determining the heating power of combustibles by the reduction of litharge, which will be noticed further on.

But there are other considerations which must likewise be taken into account in estimating the relative value of different kinds of fuel. Very many substances which are capable of giving out considerable quantities of heat cannot be used for that purpose: first, because their cost would exceed the limits of economy; and, secondly, because a too elevated temperature would be required to induce combustion. Such is the case with a great number of metals, which, under certain circumstances, are capable of evolving intense heat and light during their union with oxygen. On the other hand, there are many substances which may be made to undergo the process with comparative facility, but cannot be usefully turned to account, because they evolve obnoxious products, such as arsenical or sulphurous gases; others again require, for their combustion, a too complex apparatus, and too constant surveillance, to admit of their useful application.

The substances which combine the greatest facility of combustion with the production of a large amount of caloric, are carbon and hydrogen; and there is never wanting in the atmosphere a third, with which to combine—namely, oxygen. The product of the union of the first of these substances with oxygen, that is to say, of its combustion, is carbonic acid gas, a compound poisonous indeed when breathed alone, but destitute of odor, and colorless. Where common means of ventilation exist, there is no danger to be apprehended from this gas, and it cannot accumulate in the air to such an extent as to act injuriously; for on descending again to the earth it becomes the food of vegetals, by which it is analysed into its elements, and these are again rendered available for performing the same service. The combustion of hydrogen, or, in other words, its union with oxygen, yields only water, which, like the carbonic acid, is subjected to other transformations in nature's laboratory, whereby its elements are again separated, and therefore perform the same office over and over again without any diminution or loss of effect. It is impossible not to admire the wisdom and benevolence of that arrangement whereby these three elements are produced in quantities so enormous, they being far the most necessary materials towards the support of animal life. Regarded as sources of fuel, they are all conveniently stored in wood and other vegetals, of which a continual reproduction insures an abundant supply.

ARTICLES OF FUEL.—The substances usually employed as fuel are *wood*, *peat*, and *coal*, either in their natural state, or modified by peculiar treatment. The abundance of these in a country must always constitute a principal source of its wealth, more especially now that steam has become the moving power of manufacturing industry, as well as the great agent in locomotion. It is evident, therefore, that none of the productions of nature should be more carefully husbanded than those which constitute fuel. Every attempt also to improve the quality of inferior materials, so as to increase their efficiency as heat-producers, ought to be liberally encouraged; and some efforts in this direction have lately been made with much success.

Wood, peat, and coal, though so different in physical appearance, are nevertheless very closely allied in composition, all the three being chiefly composed of ligneous fibre, a compound of three simple elements—carbon, hydrogen, and oxygen. Physical effects have induced certain changes in some kinds of peat and coal, which cause them to differ considerably in their properties from woody fibre; but, by observing the action which analogous artificial agencies exert upon the latter, a remarkable coincidence is observed, and sufficient data are found for inferring that woody fibre is the basis of these substances, although they have passed in the course of time through various chemical transformations. The extent of the changes thus induced may be, to some degree, inferred from the phenomenon of combustion. Woody fibre, when deprived of extraneous moisture, readily bursts into a flame upon being ignited, whilst many kinds of coal do not. The difference is caused, firstly, by the states of density of these substances; and, secondly, by the absence of hydrogen and oxygen in the coal. Porosity and the presence of hydrogen in combustible bodies facilitates rapid combustion. When hydrogen is a constituent, it is liberated at a temperature below redness, in union with a portion of the carbon, from all the pores of the substance, and forms around the latter an inflammable atmosphere, which bursts into flame at slightly increased heats; the evolution of this matter leaves the remainder open to the passage of oxygen, which effects its rapid combustion.

The production of flame is always connected in a remarkable manner with the presence of hydrogen, but in some cases the phenomenon may be observed where this element is absent; thus, when pure charcoal or anthracite coal is burned in a limited supply of oxygen or air, instead of carbonic acid being generated, an inflammable gaseous body results, which re-ignites when a further quantity of air or oxygen is admitted, and produces flame. A characteristic difference is, however, observed between the sheet of light which is given out by a combustible containing hydrogen, and that from carbonic oxide; the former is luminously brilliant, as is seen in gas, whilst the latter is dull, bluish, and attenuated. The property of producing flame determines particular uses for many species of fuel, such, for instance, as choosing cannel for the manufacture of gas, and of inflammable varieties for the heating of reverberatory furnaces where the materials are at a distance from the fire. A selection of this class, for purposes where local heat is wanted, such as in the reduction of ores and in the manufacture of iron, would be injudicious, and, consequently, the less inflammable, or such as have been divested of hydrogen, are in these cases resorted to.

WOOD—*Bois*, French; *Holz*, German.—This is the name given to the hard porous tissue of plants, through which sometimes the liquid sap is raised by capillary attraction, though more generally the latter traverses between the bark and these tissues. The wood of large trees is called timber, and is generally applied to architectural and domestic uses. It is only, however, in connection with its use as a combustible or source of heat that it will be discussed in the following pages.

Chemically considered, wood is composed of several substances, both of an organic and an inorganic nature, but of these the former alone are productive of heat. Woody fibre, or the tissue already noticed, constitutes the basis of the mass, whilst the sap, water, and other matters peculiar to the species of wood, make up the remainder. All kinds contain water and woody fibre, so that the sap and extractive matters are the substances which determine the particular species of this organic production. Thus, many woods, especially the coniferous, are resinous; others, such as beech and birch, contain extractive matters; and many others, definite chemical compounds, such as tannin, and the like. All these may be removed by the successive action of water, alkalies, and alcohol; and although the principles in the several varieties are different, yet they all afford a close approximation in the quantity of carbon, hydrogen, and oxygen which the wood contains.

Various concurring circumstances tend to enhance the value of wood as a fuel, such as freedom from water, density, *et cetera*, and it is upon these qualifications that its marketable value turns.

Amount of Moisture in Woods.—A remarkable variation is observed at stated seasons, in the quantity of soluble matter—sap—which is present in all kinds of woods: thus, in spring, when the tree is in active growth, the amount of water, *et cetera*, is much greater than at the close of autumn, or the middle of winter, when it is in a kind of normal state. The practical benefit of this knowledge is, that trees, whether intended for fuel or timber, are, or should be, felled in the latter seasons; although, when they are cultivated for the principle of the sap, such as tannin, quinin, *et cetera*, it is more advantageous to cut them when the flow is at its full.

Schubler found in woods felled at the end of January and the beginning of April, an extensive difference in the amount of contained moisture, as may be seen from the appended results:—

Species.	Felling time.	Water.	Felling time.	Water.
Ash	End of January,	28·8	Beginning of April,	38·6
Sycamore	“	33·6	“	40·3
Horse Chestnut,	“	40·2	“	47·1
White Fir,	“	52·7	“	61·0

Sap is unequally disseminated in various parts of trees: in the trunk, it is accumulated more in the exterior than in the core, and still more in the branches than even in the outer portions of the trunk. Wood, cut at the proper time, retains from one-fifth to one-half its weight of moisture, part of which is lost by exposure to the air.

Schubler and Neuffer's experiments give the following as the per centage of water in the several species enumerated:—

	Water Centesimally.
Hornbeam—*Carpinus betulus*,	18·6
Willow—*Salix caprea*,	26·0
Sycamore—*Acer pseudo-platanus*,	27·0
Mountain Ash—*Sorbus aucuparia*,	28·3
Ash—*Fraxinus excelsior*,	28·7
Birch—*Betula alba*,	30·8
Wild Service Tree—*Cratægus tormin*,	32·3
Oak—*Quercus robur*,	34·7
Pedicle Oak—*Quercus pedunculata*,	35·4
White Fir—*Pinus abies dur.*,	37·1
Horse Chestnut—*Æsculus hippocast*,	38·2
Pine—*Pinus Sylvestris L.*,	39·7
Red Beech—*Fagus sylvatica*,	39·7
Alder—*Betula alnus*,	41·6
Aspen—*Populus tremula*,	43·7
Elm—*Ulmus campestris*,	44·5
Red Fir—*Pinus picea dur.*,	45·2
Lime Tree—*Tilia europæa*,	47·1
Italian Poplar—*Populus italica*,	48·2
Larch—*Pinus larix*,	48·6
White Poplar—*Populus alba*,	50·6
Black Poplar—*Populus nigra*,	51·8

From the numerous experiments performed by Chevandier, with the view of determining the loss sustained by woods of different ages, and by the several parts of the same tree when exposed to the air during stated periods, it may be inferred, that so far as the abandoning of moisture to air was observed, the soil and locality where the trees grew did not affect the results. The samples submitted to examination were exposed in a shed, which protected them from rain as well as from the sun's rays, and the moisture was determined at the several stages, by drying a portion of the sample in the form of sawdust, at a temperature of 284° Fahr. *in vacuo*, till it ceased to lose weight. By this procedure, it was found that the maximum loss by exposure was sustained, in the greater number of cases, after a period of a year and a half, although many specimens required two years to reduce their hygrometric contents in the same degree. It appeared, likewise, that the resinous varieties part with their water more freely than the non-resinous; they, on the other hand, absorb water with greater avidity when exposed to moist air than the latter. The softer non-resinous woods always contain more water when cut down than the harder kinds, but they part with it more freely, and can be desiccated to a greater extent than the latter.

The following is a synopsis of the results of researches on this subject, transcribed from the valuable treatise of Richardson and Ronalds:—

1. MEAN QUANTITY OF HYGROMETRIC WATER CONTAINED IN RESINOUS WOODS.

Parts of the Tree.	Per Centage of Water.
Trunk-wood half a-year after felling,	29
Brush-wood “	32
Young Branch-wood “	38
Trunk-wood in the driest state,	15
Brush-wood “	15
Young Branch-wood “	15

2. MEAN QUANTITY OF HYGROMETRIC WATER CONTAINED IN THE NON-RESINOUS WOODS.

Parts of the Tree.	Per Centage of Water.
Trunk-wood half a-year after felling,	26
Brush-wood “	34
Young Branch-wood “	36
Trunk-wood in the driest state,	17
Brush-wood “	20
Young Branch-wood “	19

These results may be viewed as the minima, because the single specimens would be more thoroughly exposed than if made up into stacks; and it may, therefore, be inferred, that after exposure under favorable circumstances during a year, the wood still retains about one-third of its weight of moisture, for the expulsion of which a prolonged heat is required. In ordinary air-dried firewood, this amount of water, together with that which results from the oxygen and hydrogen contained in it, is vaporized at the expense of the carbon, and the consequence is, that much of its value as fuel is lost when used in this state. In such applications where a brisk temperature is indispensable, the material is never used after merely air-drying, but is exposed to such a degree of heat as will drive off this moisture, so that, when ignited, the entire weight may be serviceable for the generation of heat. To do this thoroughly requires great care, because, unless the heat is sufficiently elevated, the moisture will not be removed, and when it is capable of exerting a thorough hydrotic effect, the constituents of the wood will be apt to arrange themselves so as to form gaseous matters, which are dispelled into the air, and thus a loss to some extent is sustained. Even when so treated that it does not retain any moisture, it becomes so hygrometric, that, upon exposure, it readily assimilates from eight to ten or more per cent. of water even in dry weather.

Density of different Woods.—When felled, nearly all kinds of wood are lighter than water, although the solid portions are possessed of a much higher density than this liquid; a few are, however, heavier than water, but these are the harder kinds, in which the cellulose is so closely packed together, that very little room is left for the retention of air. In their ordinary state, the woody matter, water, and air, concur to confer the gravity, but as the latter bodies considerably vary in amount, much difficulty is attendant upon the proper determination of the density. It will be understood, however, that so far as the moisture is concerned, it acts a neutral part, and the greater gravity of the solid portions is reduced by the volume of air in the pores. Again, as the hydrogen and oxygen of the woody fibre, as will be seen further on, are present in the ratio of their existence in water, or nearly so, and so solidified that they make up about the same volume as when actually combined in the form of water, it is evident that the greater weight of any specimen must be owing to the larger amount of carbon in the same bulk, excepting the slight difference which is due to the mineral constituents. The following table exhibits the density of several kinds of wood, according to BRISSON, water being taken as unity :—

Variety of Wood.	Density.	Variety of Wood	Density.
Pomegranate,	1·35	Maple,	0·75
Ebony,	1·33	Cherry-tree,	0·75
Dutch Boxwood,	1·32	Orange-tree,	0·70
Heart of Oak—sixty years old,	1·17	Elm—the trunk,	0·67
Medlar,	0·94	French Walnut,	0·67
Olive,	0·92	Pear-tree,	0·66
French Boxwood,	0·91	Spanish Cypress,	0·64
Spanish Mulberry,	0·89	Lime-tree,	0·60
Beech,	0·85	Hazel,	0·60
Ash—the trunk,	0·84	Willow,	0·58
Spanish Yew,	0·80	Male Fir,	0·55
Apple-tree,	0·79	Spanish White Poplar,	0·52
Dutch Yew,	0·78	Female Fir,	0·49
Plum-tree,	0·78	Poplar,	0·38
		Cork,	0·24

When common woods that are thoroughly dried and rasped so as to destroy their porosity are weighed with proper precautions, their density is found to be higher than that of water; and RUMFORD remarks that the solid portion of all the species of wood, wherever and under whatever circumstances grown, exhibits a remarkable identity in point of gravity, which he estimates at 1·46 to 1·53. It is to be observed, however, that the actual specific gravity of wood varies, in the same variety, with its age, the nature of the soil upon which it has been grown, and its site in relation to the prevailing wind; also, that young woods are specifically heavier than the older ones. The condition of the woods when the preceding densities were taken is not stated; the following table, based on different authorities, is therefore more satisfactory :—

Variety of Wood.	Hartig. I. Recently Felled.	Hartig. II. Dried in Air.	Wernek. III. Strongly Dried.	Winkler. IV. Strongly Dried.	Mushenbrock V.
Common Oak,	1·0754	0·7075	0·6441	0·663	0·929
Pedicle Oak,	1·0494	0·6777	..	0·663	..
White Willow	0·9859	0·4873	0·4464	0·457	0·585
Beech,	0·9822	0·5907	0·5422	0·560	0·852
Elm,	0·9476	0·5474	0·5788	0·518	0·600
Hornbeam,	0·9452	0·7695	..	0·691	..
Larch,	0·9205	0·4735	..	0·441	..
Scotch Fir,	0·9121	0·5502	0·4205	0·485	..
Sycamore,	0·9036	0·6592	0·5779	0·618	0·755
Ash,	0·9036	0·6440	0·6337	0·619	0·734
Birch,	0·9012	0·6274	0·5699	0·598	..
Mountain Ash,	0·8993	0·6440	..	0·552	..
Fir,	0·8941	0·5550	0·4303	0·493	0·550
Silver Fir,	0·8699	0·4716	0·3838	0·434	..
Wild Service,	0·8633	0·5910	..	0·549	0·874
Horse Chestnut,	0·8614	0·5749	..	..	..
Alder,	0·8571	0·5001	..	0·443	0·800
Lime,	0·8170	0·4390	0·3480	0·431	0·604
Black Poplar	0·7795	0·3656	..	0·346	0·383
Aspen,	0·7654	0·4302	..	0·418	..
Italian Poplar,	0·7634	0·3931	0·4402	..	..
Ground Willow,	0·7155	0·5289	..	0·501	..

The numbers given by each of the authorities in the preceding table can only be received as an approximation to the truth; but WINKLER'S are probably the most trustworthy, because, in making his observations, the bulk of wood—one cubic inch—was the same in every instance, and the specimens were exposed in a heated chamber during six months, so that all contained an equal amount of water at the time of the experiment.

The principal difficulty experienced in attempting to determine the gravity of different kinds of wood, arises from the absorption of air into the pores and its subsequent expulsion. MARCUS BULL in his experiments removed this cause of error to a great extent, by coating the samples with a varnish having the same gravity as water. This insured the retention of the air in the pores, and admitted of arriving at a true approximation, although this appeared less than when quantities of the enclosed air were allowed to escape, as generally happens on immersing dried wood in water. Before citing his results, however, the appended table, containing KARMARSH'S recent determinations, is placed before the reader, as affording a comparative view of the specific gravity of different kinds of wood in the green and in the dried state, with the mean weight of one cubic foot of the dried material :—

Variety of Wood.	Specific Gravity.				Mean weight of one cubic foot of Air-dried Wood in pounds.
	In the Green State.		In the Dried State.		
	Limits.	Mean	Limits.	Mean.	
Maple,	0·843 .. 0·944	0·893	0·645 .. 0·750	0·697	37 pounds.
Apple,	0·960 .. 1·137	1·048	0·734 .. 0·793	0·763	41 “
Birch,	0·851 .. 0·987	0·919	0·688 .. 0·738	0·713	38 “
Pear,	.. .. ..	..	0·646 .. 0·732	0·689	37 “
Red Beech,	0·852 .. 1·109	0·980	0·690 .. 0·852	0·771	41 “
Box,	.. .. ..	..	0·912 .. 1·031	0·971	52 “
Cedar,	.. .. ..	..	0·561 .. 0·575	0·568	30 “
Ebony,	.. .. ..	..	1·187 .. 1·331	1·259	67 “
Oak,	0·885 .. 1·062	0·973	0·650 .. 0·920	0·785	42 “
Alder,	0·809 .. 0·994	0·901	0·505 .. 0·680	0·592	31 “
Ash,	0·778 .. 0·927	0·852	0·540 .. 0·845	0·692	37 “
Pine,	0·848 .. 0·993	0·920	0·454 .. 0·481	0·467	25 “
Scotch Fir,	0·811 .. 1·005	0·908	.. ..	..	“
Larch,	0·694 .. 0·924	0·809	0·565	0·565	30 “
Lime,	0·710 .. 0·878	0·794	0·559 .. 0·604	0·581	31 “
Poplar,	0·758 .. 0·956	0·857	0·383 .. 0·591	0·487	26 “
Guaiac,	.. .. ..	..	1·263 .. 1·342	1·302	69 “
Silver Fir,	0·894	0·894	0·498 .. 0·746	0·622	33 “
Elm,	0·878 .. 0·941	0·909	0·568 .. 0·671	0·619	33 “
Willow,	0·838 .. 0·855	0·846	0·392 .. 0·530	0·461	25 “
White Beech,	0·939 .. 1·137	1·038	0·728 .. 0·790	0·759	40 “

The Hanoverian pound, which is that given in the preceding table, is equivalent to 1·031114 English. It may be seen from this table, that most of the results show the specific gravity of the samples examined to be about half that of water. A fair average of the value of wood, subjected to desiccation in open sheds, can only be arrived at by ascertaining the weight.

Marcus Bull has shown that, for every fifty-six parts of actual wood contained in an ordinary stack, there are forty-four of unoccupied space. In prosecuting his inquiries into this subject, he determined the real amount of matter in a given bulk of wood, the tabulated specific gravity having been previously ascertained by coating the wood with varnish as already stated :—

Species of Wood.	Lbs. avoirdupois in a cubic metre = 35 3 cubic feet English.	Lbs avoirdupois in a cubic foot	Specific Gravity.
Walnut—with scaly bark,	1227·6	34·7	1·000
White Oak—Chestnut,	1075·8	30·5	0·885
American Ash,	919·4	26·0	0·772
Beech,	880·0	24·9	0·724
Hornbeam,	875·6	24·8	0·720
American Elm	704·0	19·9	0·580
Yellow Pine	668·0	18·9	0·551
Birch—Poplar-leaved,	647·6	18·3	0·530
American Horse Chestnut,	633·6	17·9	..
Italian Poplar,	481·8	13·6	..

The following results obtained by M. Berthier may also be useful :—

Nature of the Wood.	State of the Wood.	Weight of a cubic metre = 35·317 English cubic feet in pounds avoirdupois.	Weight of a cubic foot in pounds.
Forest Oak from the environs of Moulons,	A year cut in cleft logs,	826·9	26
“ “ “	Cut in four,	1135·6	34
Oak of the forest of Monadier, near Moulons,	Large wood cut for three years' cleft,	875·0	26·3
“ “ “	Cut in four,	1069·4	33
Oak of the environs of Cahors,	A year cut,	1157·6	36
Charring Oak,	Same—length thirty inches,	485·1 to 577·7	15 to 18
Beech of the neighborhood of Moulons,	Cut in large billets,	882·0	30
“ “ “	Partly worm-eaten,	826·8	26
Aspen for charring,		419 to 485·1	13 to 15
Birch from the neighborhood of Moulons,	In very large billets,	970·2	30
Fir from Montiers,	In large wood,	661·5 to 749·7	21 to 22

Even these numbers do not take cognizance of the water which is present in air-dried wood to the extent of a quarter of its weight; hence, to find the real value in ligneous matter, these results should be multiplied by three-fourths.

At best, the density of wood leads but to a very vague and unsatisfactory conclusion regarding its heating power, although the fact of one sample being better than another in this respect may generally be inferred from its greater specific weight, which is a proof that it contains more carbonaceous matter in the same bulk. The condition of equal dryness, however, should not be overlooked, as without taking this into consideration the gravity deduced would be erroneous. From two-fifths to one-half the bulk of a stack of wood is interstitial space, even when the logs are of fair proportions; this is, however, much increased when small or crooked billets enter into its composition. Hence, in a stack, the per centage of solid matter compared with the bulk of the whole is very much less than that given in Bull's table. At the same time, it is only the quantity of woody matter that renders the material valuable as fuel; and a much nearer approximation to this can be arrived at when it is purchased by weight, than if the content is estimated by measurement. When, however, the purchaser is compelled to adopt the latter course, he should remember that the largest and straightest, as also the driest and densest varieties, are the surest to afford him an adequate value; the light, soft, and green woods not possessing sufficient matter to endue them with heating power in proportion to their bulk.

Value of different kinds of Wood as Fuel.—Very many considerations are to be taken into account in selecting wood as fuel—namely, the quantity of heat to be generated, the distance to which its effects are required to extend, and the length of time that the temperature must be sustained.

When soft light woods are burned, their action is brisk but transitory, their porosity favoring the rapid evolution of the volatile inflammable gases to which a part of their substance is converted by the heat; moreover, this looseness of texture allows the transmission of air freely through the mass of charcoal left, and, consequently, effects its rapid combustion. A remarkable exception indeed is cork-wood, which, although very light, affords more charcoal proportionally than any other species. When the wood is hard and compact, the heat cannot traverse it so freely; and the result is, that the interior portions undergo a kind of consecutive distillation, the volatile matters being slowly disengaged from the surface. When these have produced their effect, a charcoal remains of a dense and close character, weighing fifteen or twenty times more than that which light wood produces. Submitted to combustion, the charcoal from dense wood burns much more slowly, owing to the smaller surface which it presents to the air, than that from the softer kinds. These facts lead to the conclusion, that the principal effect of soft light woods is produced by the flame, the charcoal they afford being comparatively of little value. The contrary is the case with heavy woods, the flame from which is feeble compared with the others; but their charcoal is far superior, and more than counterbalances the difference.

It has been shown, in a preceding part of this article, that incandescent charcoal is very much superior to flame in radiating power; or, in other words, the quantity of caloric given off from charcoal is considerably greater than that emitted from flame; and as the denser woods produce, for equal weights, a much larger amount of charcoal than the lighter kinds, it follows that much more heat will result from the former. Nevertheless, although light woods are less adapted for all heating operations in which radiation plays an important part, yet they may be employed with advantage where it is required to communicate an elevated temperature to objects distant from the fire-place, or a uniform temperature to solid bodies in large masses. Such are the reasons of their being preferred for glass-works, porcelain manufactories, *et cetera;* and even if a naturally dense material be employed for these purposes, it is brought to a suitable state by splitting it up into thin pieces, so as to render the combustion quicker, or to avoid the introduction of a useless mass of air into the furnace. On the contrary, blocks of dense wood are preferable for the heating of boilers, and other similar purposes, because, in this case, the radiant matter is required to act directly on the surface to be heated, which communicates by contact the heat to the liquid in the interior, through which it is then diffused by convection. The superiority of the denser over the softer woods for consumption in ordinary household fires, where radiation performs the most important part, is a fact universally recognised in practice. For stoves, also, and for heating apparatus in general, the former are found to be more advantageous, because they afford a much more regular and prolonged heat than the lighter woods, without involving the necessity of constantly adding fresh material to maintain the fire. On the other hand, apart from these considerations, the actual calorific effect of the same weight of dense and light wood is nearly equal. This has been proved experimentally by Marcus Bull. Operating with a stove so constructed as to lose the least possible amount of heat, he found that the widest proportions between numerous specimens were as fifteen to sixteen.

In England, where wood is scarce and coal fields are numerous and extensive, the former is little employed as a fuel, except for some special purposes: but this is not the case in all other nations, and some European states in particular are almost entirely dependent upon wood for common consumption. On the Continent, fire-wood is divided into three kinds, namely, *new wood, float wood,* and *peeled wood.* The first is that which has been conveyed by boat or waggon from the forest to the place of its consumption; the second, that which has been floated upon the waters in the form of rafts, a mode of conveyance which causes a considerable quantity to be submerged during the passage; lastly, the peeled wood is limited to oak and certain other species, the barks of which have been removed for the sake of the principle they contain: it is generally composed of the smaller branches, and used in dwellings. Much of the value of the floated wood is lost by its submergence in the water, and this, to a great extent, counteracts the advantages of cheap transport. The loss arises from the solution of the principle of the sap in the water, and is visible in the density as well as in the volume, sometimes amounting to one pound per cubic foot.

Solid Constituents of Wood.—Fibrous matter, water, sap, and mineral salts, are the proximate principles of wood of every description. The amount of water contained in different woods has already received a share of attention, and as the sap is of a different nature in every species, to enlarge upon it in all its varieties would unduly prolong this article. The further explanation of the proximate principles of wood will, therefore, be confined to the cellulose, lignin, or woody fibre, and the mineral constituents.

Lignin.—Woody Fibre or Lignin constitutes, as already stated, the main bulk of trees, and mostly all plants, varying in texture from the delicate and friable pith to the hard shells of the seeds, and the more dense and indurated vegetal ivory or perisperm of the seeds of the phytelephas. Regarded in conjunction with the mineral matters, it may be termed the skeleton of their structure, wherein is contained the various secretions and other principles. When the fine raspings of wood are treated successively with boiling alcohol, water, weak solutions of potassa, dilute hydrochloric acid, and ultimately boiled repeatedly with distilled water, there remains a white substance, which, when dried at 212°, is this *cellulose* or *lignin.* Not only may it be procured from the hard wood; but the pith of trees and plants yields it even more freely. If this pith be reduced by rasping, and then washed successively with hot and cold water, digesting in a weak solution of potassa, and afterwards subjecting it to the action of chlorine gas, the fibrin will be readily obtained. To complete the process, however, the digestion with the alkali is repeated, and this is succeeded by another with acetic acid, when, after affusing well with distilled water, and drying, a very pure lignin results. Many substances—such, for instance, as linen, cotton, paper, *et cetera*—afford lignin in a much purer state than wood, owing to the treatment which the fibre of flax and cotton undergoes to prepare it for those manufactures.

Pure lignin is tasteless, colorless, and insoluble in water, alcohol, ether, and essential oils; it has a specific gravity of 1·5, and is resolvable into other compounds by acids, such as nitric and sulphuric. The latter, in a concentrated state, converts it first into gum or dextrin, which may be afterwards resolved into grape-sugar. To effect this, one hundred parts of lignin—or clean bleached cotton or linen, answers the purpose—are treated with one hundred and forty of concentrated sulphuric acid in such a manner as to avoid the evolution of heat, or any charring; the mixture will readily admit of being triturated into a magma, which is soluble in water. By treating the aqueous solution of this mucilaginous matter with chalk, and straining or filtering, a liquid is obtained, from which alcohol separates a gummy precipitate; and this, after being elutriated with the spirit, and then dissolved in water acidulated with sulphuric acid, and boiled for some time, passes into grape-sugar.

It might be inferred from these results, that strong sulphuric acid converts lignin into amidin and dextrin; and, finally, into glucose or grape-sugar; yet the evidence in proof of the first change is not very distinct, although, on the application of the sulphuric acid to the substance, if a solution of iodine be added, a deep blue tint will appear. To show that the transformation to starch is effected, Schleiden directs that clean cotton wool be wetted with water, then squeezed dry, and afterwards spread upon a flat dish, and moistened with a mixture of three parts of sulphuric acid and one of water; after about half a minute, an aqueous solution of iodine is added. With this treatment the blue iodide of starch does not fail to make its appearance.

Sulphuric acid reacts with great vigor upon wood and lignin, especially when heat is applied, giving rise to sulphurous, acetic, and formic acids, besides producing a black magma, from which water washes out those bodies, and leaves the carbonaceous residue to the extent of forty-three per cent. of the wood employed.

Nitric acid, in the concentrated state, decomposes lignin, changing it into the peculiar body xyloidin, which has nearly the same characteristics as that obtained from starch by similar treatment. The *gun-cotton* of Schönbein, which is prepared by immersing cotton wool for a short time in equal parts of concentrated sulphuric and nitric acids, and washing under a stream of water and drying, is probably either a peroxide or a nitrate of lignin.

Hydrochloric acid, on being boiled with lignin, turns red, and ultimately brown. In the solid state, it becomes black, but does not dissolve in the acid. When this substance is washed and dried, it burns with flame, showing that it is only modified lignin, and not entirely carbonized. Fused potassa, or a strong solution of this alkali, changes a portion of the matter into oxalic and acetic acids, which combine with the base; the alkaline liquor, when treated with acids, parts with a modified lignin which is blued by iodine.

From what has been said of the behavior of lignin, more especially with sulphuric acid, it may be inferred that its composition is analogous to that of amylaceous compounds, or, in other words, that it is made up of the elements, carbon, hydrogen, and oxygen; the latter two being in that proportion in which they form water. Gay-Lussac and Thenard were the first to arrive at the conclusion that this proportion existed between these two elements, and the analyses of Prout and others corroborated this view of the subject. To show the identity of lignin in the extensive circle of plants in which it is found, was a work undertaken and successfully accomplished by Prout—not, however, by having recourse to numerous analyses of the principle prepared from different plants, but by taking two products of very opposite physical characteristics, and submitting them to ultimate analysis. These were portions of lignin from the *box* and *willow*; the former being one of the densest, and the latter one of the lightest species of woods. After preparing the lignin by repeated treatments with boiling water and alcohol, *et cetera*, it was submitted, after desiccation in air, to analysis, which gave the following numbers :—

	Centesimally.	
	Box.	Willow.
Carbon,	42·7	42·6
Water,	57·3	57·4
	100·0	100·0

By exposing the lignin thus analysed to a temperature of 212°, as long as loss was sustained, it was found that 14·6 per cent. of the weight of the box and 14·4 per cent. of the willow disappeared. Upon examination, the dried substance showed the annexed proportions :—

	Centesimally.	
	Box.	Willow.
Carbon,	50	49·8
Water,	50	50·2
	100	100·0

By comparing these numbers with the figures given by GAY-LUSSAC and THENARD, as representing the composition of the lignin of beech and oak, namely :—

	Oak.	Beech.
Carbon,	52·53	51·45
Water,	47·47	48·55

or specifying the quantity of the water-producing elements thus :—

Carbon,	52·53	51·45
Hydrogen,	5·27	5·41
Oxygen,	42·20	43·14

the coincidence of composition will become apparent. LIEBIG assumes, from the analysis of GAY-LUSSAC and THENARD, that the formula is $C_{36}\ H_{22}\ O_{22}$; but calculating from the numbers obtained by PROUT, it is $C_{36}\ H_{24}\ O_{24}$.

By the action of heat, the hydrogen and oxygen in this body are made to unite, and, consequently, so far as the estimation of the value of lignin as a fuel is measured by the oxygen assimilated, they play no part, although it must be admitted that a certain quantity of caloric is disengaged by the chemical action which is produced by their union, notwithstanding that this may be rendered latent by the dispersion of the water so generated in the form of steam. It is, therefore, the carbon which operates in developing caloric by combining with oxygen, of which one hundred and thirty-eight parts are required to effect the conversion of one hundred parts of wood, represented by 52 of carbon, into carbonic acid. The caloric produced in this reaction is capable of melting 4,888 parts of ice, or of raising 3,666 parts of water from 32° to 212°. With these theoretical deductions, the practical results of RUMFORD and HASSENFRATZ are in perfect accordance, giving 3,600 to 3,680, as the equivalent for dry woods. It must be observed, however, that all the heat is not produced by the carbon of lignin, as assumed in the above calculation; because the principle of the sap is retained. This, however, approaches so near in composition to woody fibre, and its quantity is so minute, that it does not cause any remarkable difference between the results of the ultimate analysis of dry wood and pure lignin, as the following table drawn up from the determinations of SCHÖDLER and PETERSON shows :—

Species of Wood.	Carbon.	Hydrogen.	Oxygen.
Pure woody fibre,	52·65	5·25	42·10
Quercus robur,	49·43	6·07	44·50
Fraxinus excelsior,	49·36	6·075	44·57
Acer campestris,	49·80	6·31	43·89
Fagus sylvatica,	48·53	6·30	45·17
Betula alba,	48·60	6·375	45·02
Ulmus campestris,	50·19	6·425	43·39
Populus nigra,	49·70	6·31	43·99
Tilia europæa,	49·41	6·86	43·73
Salix fragilis,	48·44	6·36	44·80
Pinus abies,	49·95	6·41	43·65
Pinus picea,	49·59	6·38	44·02
Pinus sylvestris,	49·94	6·25	43·31
Pinus larix,	50·11	6·31	43·58

It should be remembered, however, that the ash which, as will be presently seen, averages from one per cent. to a much higher proportion, has not here been taken into account, and, consequently, that the difference is greater than it would be, if the mineral ingredients were left out. CHEVANDIER has investigated some woods, taking cognizance of this fact, and the several specimens being dried at 284°, afforded the following results :—

ELEMENTARY COMPOSITION OF SOLID WOOD AFTER DEDUCTING THE ASH.

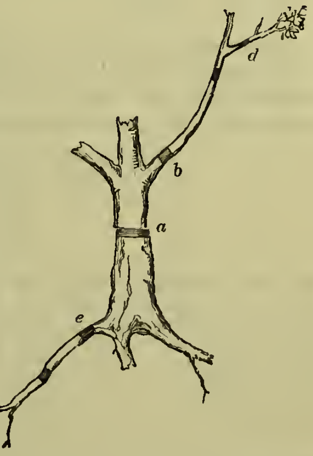
	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Mean of Analyses
Beech,	49·89	6·07	43·11	0·93	7
Oak,	50·64	6·03	42·05	1·28	5
Birch,	50·61	6·23	42·04	1·12	4
Aspen,	50·31	6·32	42·39	0·98	3
Willow,	51·75	6·19	41·08	0·98	2

ELEMENTARY COMPOSITION OF BRUSHWOOD AND BRANCHES AFTER DEDUCTING THE ASH.

	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Mean of Analyses.
Beech,	50·08	6·23	41·61	1·08	8
Oak,	50·89	6·16	41·94	1·01	4
Birch,	51·93	6·31	40·69	1·07	3
Aspen,	51·02	6·28	41·65	1·05	2
Willow,	54·03	6·56	37·93	1·48	2

On the whole, it appears from what has been stated, that carbon, oxygen, hydrogen, and nitrogen, are the essential ultimate elements of vegetal products, and that the proportion in which they combine is very nearly the same in different plants. It is, therefore, not a little remarkable, that the composition of even the same plants is found to vary slightly in different parts. This might be expected in regard to the distinct organs —such as the pith, the wood, the bark, and the leaves —but not in regard to different complete portions of the same organic structure. Even in the latter, however, a sensible variation exists in the root, the trunk, and larger or smaller branches. M. VIOLETTE examined various portions of the completely organized structure of the same tree, with the view of determining this point. The subject of his experiments was a healthy cherry-tree, thirty years old, which was carefully dug up in the month of October, taking care to preserve the roots and rootlets entire and without injury. Samples were taken from the trunk, the branches, and the roots, as represented in Fig. 16, at *a*, *b*, *c*, *d*, *e*, *f*, *g*—all cut of equal thickness and enclosed in paper capsules, which were deposited during five hours in the bottom of a receiver, in which a current of steam from the boiler was made to circulate. By this exposure to air and to the temperature of about 172°, they all acquired an equal desic-

Fig. 16.



cation, and, after this treatment, they were well dried by enclosing them in flasks. The results which were arrived at by submitting these woods to analyses are subjoined, and the operator states that they were not accepted till the repetition of the process corroborated them:—

COMPOSITION OF WOOD CUT FROM VARIOUS PARTS OF THE SAME TREE.

Nature of Wood.		Elementary substances found in 100 parts of wood. Carbon.	Hydrogen.	Oxygen and Nitrogen.	Ash.
Leaves,		45·015	6·971	40·910	7·118
Small branch,	Bark,	52·496	7·312	36·737	3·454
	Wood,	48·359	6·605	44·730	0·304
Middle-sized do.	Bark,	48·855	6·342	41·121	3·682
	Wood,	49·902	6·607	43·356	0·134
Large do.,	Bark,	46·871	5·570	44·656	2·903
	Wood,	48·003	6·472	45·170	0·354
Trunk,	Bark,	46·267	5·930	44·755	2·657
	Wood,	48·925	6·460	44·319	0·296
Large root,	Bark,	49·085	6·024	48·761	1·129
	Wood,	49·324	6·286	44·108	0·231
Middle-sized do.	Bark,	50·367	6·069	41·920	1·643
	Wood,	47·390	6·259	46·126	0·223
Rootlet, with branch,		45·063	5·036	43·503	5·007

Mineral Constituents.—When wood is burned, it always leaves a certain amount of residue or ash, which consists of various alkaline and earthy salts that have been taken up from the soil with the sap. The bases or metallic oxides of this ash are potassa, soda, lime, oxide of iron, and sometimes oxide of manganese; one or more of which are united with silicic, carbonic, sulphuric, and phosphoric acids, chlorine and sulphur. All woods have not the same per centage of inorganic matter contained in them, and, as may be seen in the preceding table, it varies remarkably in different parts of the same tree, and also with its age.

According to SAUSSURE, the quantity of ash yielded by—

1000 parts of barked young oak branches was....	4 parts.
1000 parts of their bark,	60 "
1000 parts of an oak trunk 56 feet diameter,	2 "
1000 parts of its bark,	60 "

BERTHIER, KARSTEN, CHEVANDIER, and others, have likewise directed their attention to this subject, employing air-dried wood as the subject of their experiments. The results are appended:—

ASH IN A HUNDRED PARTS.

	Berthier.	Karsten.		Chevandier.		
		In young wood.	In old wood.	Solid stem wood.	Wood of branches.	Brush-wood.
Silver fir—*Pinus picea*,	0·83	0·15	0·15	—	—	—
Birch,	1·00	0·25	0·30	0·57	1·00	0·48
Scotch fir, *Pinus sylvestris*	1·24	0·12	0·15	—	—	—
Oak,	2·50	0·15	0·11	1·94	1·49	1·32
Lime,	5·00	0·40	—	—	—	—
Fir—*Pinus abies*,	—	0 23	0·25	—	—	—
White beech,	—	0·32	0·35	0·73	1·54	0·72
Alder,	—	0·35	0·40	—	—	—
Red beech,	—	0·38	0·40	—	—	—
Aspen,	—	—	—	1·49	2·38	—
Willow,	—	—	—	2·94	3·66	—

ACTION OF HEAT ON WOOD.—Having explained the constituents of wood, it remains now to examine the effects of heat upon it. As the tendency of caloric is to subvert the power of the existing affinity between the elements of complex bodies, as well as to change their physical appearance, the simpler the substances submitted to its action—that is, the fewer elements composing them—the greater is the force with which they are held in combination, and the better do they resist the influence of caloric. When several bodies enter into the composition of a substance, it readily yields to the decomposing effects of fire, especially if the constituents have an affinity for one another, whereby simpler combinations are produced. Products of organic growth are generally of this class, as they include several elementary matters which have a remarkable tendency to arrange themselves into simpler and more persistent compounds. Some of the ingredients of these bodies are of a volatile nature; hence, as soon as the force of the heat applied overbalances that of the affinity which binds them together in the peculiar state in which the vitality of the plant arranges them, they assimilate and disperse, whilst others are left in the solid state. When the matters submitted to the action of heat are out of contact with air or oxygen, the quantity and number of the compounds formed depend, for the most part, upon the intensity of the temperature applied; but when oxygen or air is admitted, and the action of the heat is still exerted, the bodies, already modified, will undergo another change, from which will result compounds of the simplest and most permanent character. The latter transformation is always accompanied by the phenomena of combustion, whilst the former is termed dry distillation.

The constituents of organic matters, acted upon by heat in the presence of air or oxygen, unite with the latter element, and form with it the simplest and most stable compounds which it is possible for them to enter into. This is shown in the conversion of the carbon, hydrogen, and oxygen of such bodies into carbonic acid, CO_2, and water, HO—two of the simplest, and at the same time most permanent combinations. In the other method of acting with heat upon organic substances—that is to say, in close vessels or out of contact with air—the results are by no means so simple as those just described; because the conditions necessary for caloric to exert its full effect upon them are not supplied; and hence, although the compounds formed are not so complex, and are more permanent than those from which they have been generated, yet they are far from being the simplest and the most persistent.

From the moment when the decomposing agency of heat begins to overcome the existing affinity of the elements in the organic body, three circumstances concur, either to multiply the formation of distinct but definite compounds, or to yield particular ones in larger quantities: these are, as already intimated, the temperature; the natural affinity of the existing elements, more especially at the moment of their liberation in the nascent state; and, lastly, their volatility. The effects of the temperature are first directed to the expulsion of oxygen and hydrogen, two elements which, from their permanently gaseous nature, are disengaged; they have, however, a very powerful affinity for one another, and, consequently, at the instant of their liberation, this affinity is exerted, and

WELLCOME INSTITUTE LIBRARY